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PART I

BIOVENTING TEST WORK PLAN FOR IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND IRP SITE SS-15 (POL FUEL DEPOT) SHAW AFB, SOUTH CAROLINA

PART II

DRAFT INTERIM BIOVENTING PILOT TESTS RESULTS REPORT IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND IRP SITE SS-15 (POL FUEL DEPOT) SHAW AFB, SOUTH CAROLINA

Prepared for

Air Force Center For Environmental Excellence
Brooks AFB, Texas

and

20th Fighter Wing CES/CEV
Shaw AFB, South Carolina

ES ENGINEERING-SCIENCE

AQM01-03-0559

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PART I

BIOVENTING TEST WORK PLAN FOR IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND IRP SITE SS-15 (POL FUEL DEPOT) SHAW AFB, SOUTH CAROLINA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AFB, TEXAS

and

20TH FIGHTER WING CES/CEV
SHAW AFB, SOUTH CAROLINA

May 1994

Prepared by:

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1700 Broadway, Suite 900
Denver, Colorado

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PART I

BIOVENTING TEST WORK PLAN FOR IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND IRP SITE SS-15 (POL FUEL DEPOT) SHAW AFB, SOUTH CAROLINA

1.0 INTRODUCTION

This site-specific work plan presents the scope of proposed bioventing pilot tests for *in situ* treatment of fuel-contaminated soils at two sites at Shaw Air Force Base, Sumter, South Carolina. The first bioventing test site is located at Former Fire Training Area #1, designated as Installation Restoration Program (IRP) Site FT-01. This IRP site comprises base Operable Unit #4 (OU-4).

The second bioventing test site is located at OU-1 within the confines of the base Petroleum, Oil, and Lubricant (POL) Bulk Fuel Storage Facility (POL Depot). The pilot test area will be located in the vicinity of a former 1,000-gallon reclaimable fuels underground storage tank (UST). The proposed test area is immediately adjacent to IRP Site SS-15, the IRP designation originally assigned to a leaking 25,000-gallon UST containing JP-4 jet fuel (UST #5). Based on information provided by Shaw AFB, all leaking USTs and ancillary piping within the POL Depot are now considered a part of IRP Site SS-15, since releases from an unknown number of the UST systems have merged to form a somewhat contiguous plume of soil and groundwater contamination within the facility. For these reasons, the bioventing pilot test location at the POL Depot is referred to as IRP Site SS-15 in this work plan.

The test objectives, test protocols and field activities presented in this work plan will be similar for both pilot test sites. Minor modifications will be made to the individual bioventing systems as required to accommodate site-specific conditions.

1.1 Pilot Test Objectives

The proposed bioventing pilot tests have three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade the fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated below regulatory standards. If bioventing proves to be a feasible technology for the sites, pilot test data can be used to design full-scale remediation systems and to estimate the time required for remediating soils to regulatory standards. An added benefit expected at the pilot testing sites is that a significant amount of the fuel contamination should be biodegraded during the test, since the testing will take place within the most contaminated soils that have been detected on the site.

The pilot test at Site FT-01 will involve two shallow vertical air injection vent wells and a blower capable of sustaining a flow rate of at least 40 standard cubic foot per

minute (scfm). The pilot test system at Site SS-15 will have a similar design, although only one deep vent well is proposed for this site. Previous bioventing experience at bases with site conditions similar to Shaw AFB indicate that a radius of oxygen influence of 30 to 50 feet is reasonable for each vertical vent well operated at a site with a moderate to deep water table. By comparison, the effective radius of oxygen influence is expected to be somewhat less when operating a shallow vent well on a site with a relatively shallow water table. The design flow rate and actual radius of influence for any one site will depend on soil properties, depth to groundwater, and other factors.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol For A Field Treatability Test For Bioventing*. This protocol document is a supplement to the site-specific work plan and it will also serve as the primary reference for pilot test designs and detailed test objectives and procedures. Unless otherwise noted, test procedures outlined in the protocol document will be used during the bioventing pilot tests at Shaw AFB.

2.0 SITE DESCRIPTIONS

This section provides a description of the site conditions and historical summaries of previous investigations at Site FT-01 and Site SS-15. This information was derived from previous site assessment reports and other pertinent information provided by Shaw AFB personnel. Additional data were collected from each site during the initial site visits and preliminary site screening activities. Figure 2.1 shows the general location of both bioventing test sites with respect to the base.

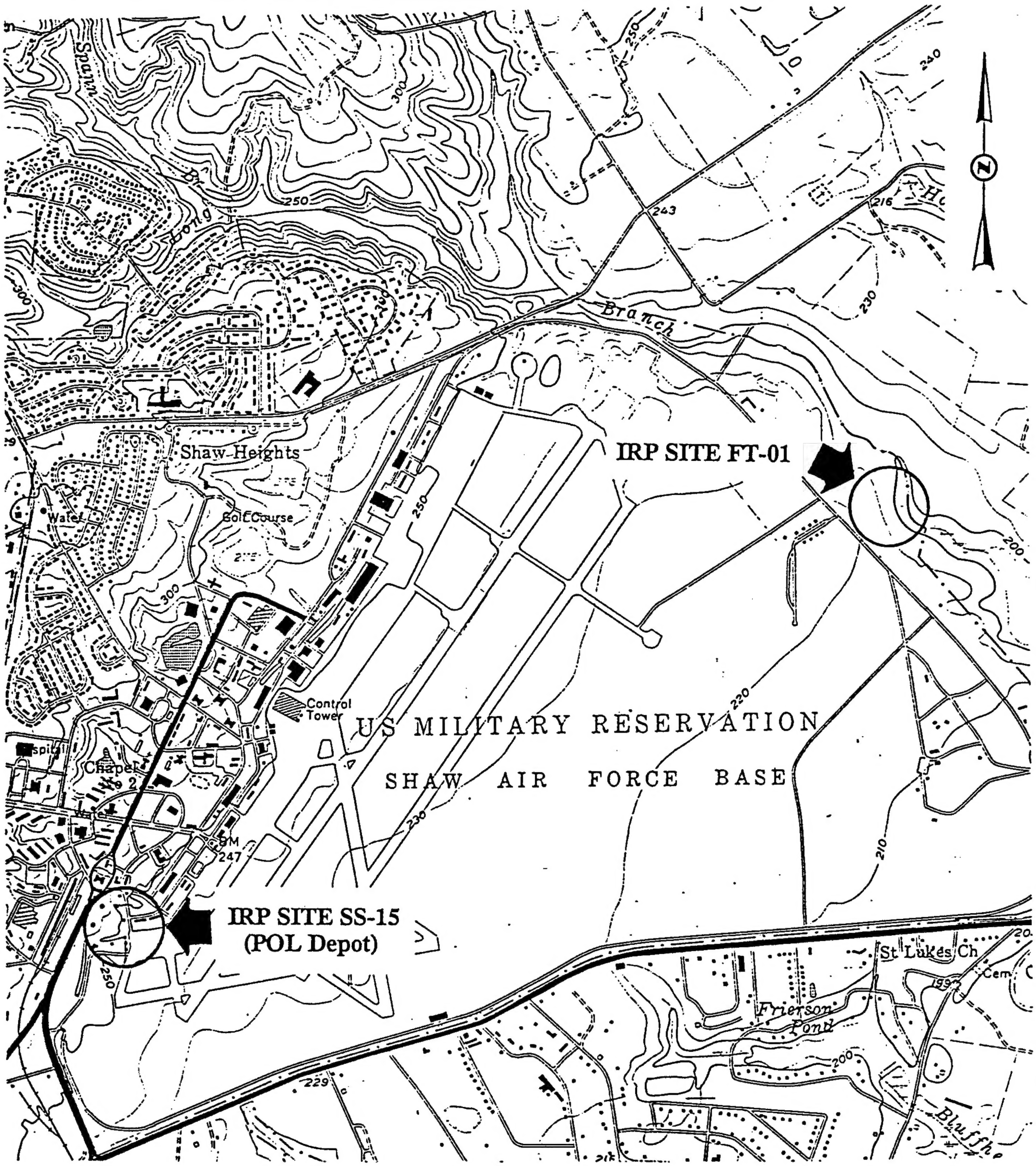
2.1 Site FT-01 (Former Fire Training Area #1)

2.1.1 Site Location and History

Site FT-01 (Former Fire Training Area #1) is approximately 13 acres in size. The site is located adjacent to Patrol Road on the east-northeast part of the base (see Figure 2.1). The site is primarily a mixture of woodlands and open areas with sparse vegetation. It is bordered to the west by Patrol Road and to the north and east by Long Branch and the base property boundary (fenced). Surface drainage is toward the north and east to Long Branch which drains into nearby Booths Pond. Figure 2.2 shows a site plan for Site FT-01 with the location of existing monitoring wells.

Former Fire Training Area #1 was used for weekly fire training exercises from 1941 to 1969. The former fire training areas consisted of bermed fire pits that were periodically moved during operation of the facility. Remnants of the bermed, primary burn pit are still visible on the site, as depicted in Figure 2.2. A variety of combustible wastes were burned during the fire training exercises, including jet fuel, waste oils, hydraulic fluids, spent solvents, contaminated fuels, and napalm. These waste materials were hauled to the site in drums and poured into the unlined burn pits. Some of the empty waste drums were reportedly buried on-site. Extinguishing agents used on the fires included water, carbon dioxide, protein foam, and Aqueous Film Forming Foam. Portions of the site have poor surface drainage due to inadequate grading following closure of the facility (Law, 1991).

Figure 2.1



2000 1000 0 2000'

Approximate Scale in Feet

From: U.S.G.S. Sumter West, SC Quadrangle
(7.5 Minute Topographic Map – Revised 1982)

Location Map for
Bioventing Project Sites

IRP Sites FT–01 and SS–15
Shaw AFB
Sumter, South Carolina

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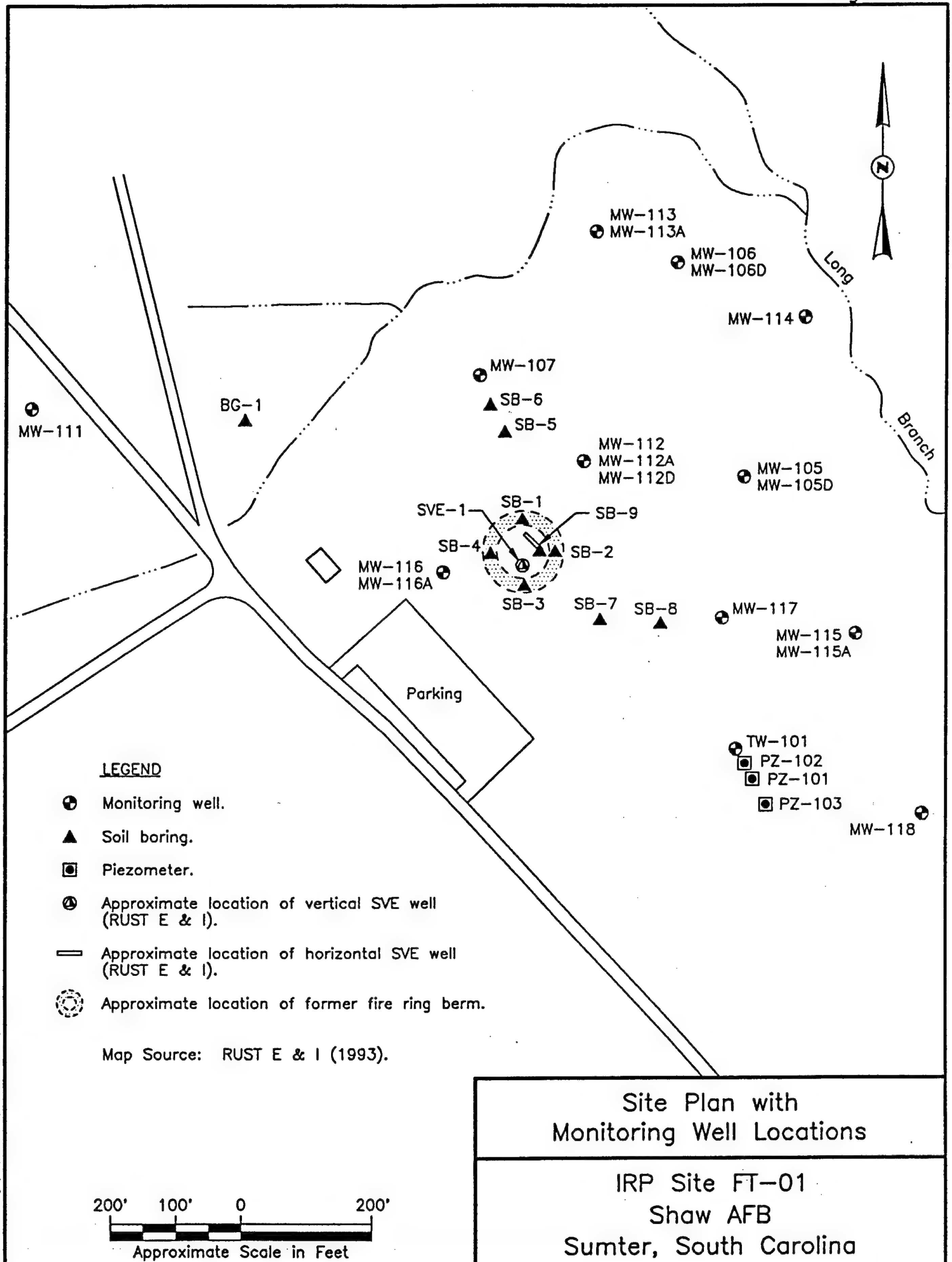
Figure 2.2



Site Plan with Monitoring Well Locations

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

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2.1.2 Previous Investigations at Site FT-01

Groundwater monitoring wells and soil borings at Site FT-01 were installed during several phases of the Remedial Investigation/Feasibility Study (RI/FS). The RI/FS field investigations were performed by both Law Environmental, Inc. (1988-1991) and RUST Environment & Infrastructure (1991-1994). A total of 18 shallow and deep groundwater monitoring wells, 1 test well, 3 piezometers, 10 soil borings, and 2 soil vapor extraction (SVE) wells were installed at Site FT-01 during the RI/FS (see Figure 2.2). Split spoon soil samples were collected during the monitoring well and soil boring installations. Soil samples were analyzed for diesel range organics (DRO) and for volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylenes (BTEX). Groundwater samples were analyzed for VOCs, semi-volatile organic compounds (SVOCs), pesticides, and metals.

The highest concentrations of fuel-contaminated soils occur in shallow soils at the primary burn pit. Soil DRO concentrations of 9,500 milligrams per kilogram (mg/kg) were detected in samples collected from 0 to 3 feet at SB-4 near the edge of the primary burn pit (see Figure 2.2). DRO concentrations up to 6,300 mg/kg were detected in the 6 to 8-foot sampling depth at soil boring SB-1. Other isolated, less extensive areas of elevated soil DRO concentrations were detected away from the primary burn pit. These localized areas of soil contamination probably represent secondary burn pits periodically used at the site.

Detected total VOCs, including BTEX compounds, were less than 5 mg/kg in shallow soil less than 3 feet deep. Total VOC concentrations in soils generally increased with depth, where up to 35 mg/kg was detected in SB-4 at the 6 to 8-foot depth. Groundwater samples also contained various VOCs, including BTEX compounds, Trichloroethane (TCA), 1,2-dichloroethene, 1,1-dichloroethane, and 1,1-dichloroethene. Aqueous samples from well MW-117 contained the highest VOC concentration with 14,000 micrograms per liter (ug/L) of TCA. Additionally, several SVOCs, metals, and pesticides are present in low concentrations in groundwater. Liquid-phase product has not been detected at the site.

RUST E&I conducted short-duration SVE pilot tests and a 2-month bench-scale bioremediation study at the site in 1993 to support the ongoing RI/FS. A vertical SVE well and a horizontal SVE well were installed in the former primary burn pit as part of this study (see Figure 2.2). The objectives of the short-term SVE pilot tests were to collect operating data for full-scale design, to monitor oxygen-enhanced respiration rates of indigenous microorganisms during and after the SVE process, and to compare the operating effectiveness of horizontal SVE wells versus vertical SVE wells. Measurements of field respiration rates had limited success during the tests, and there were significant problems with both air short-circuiting at the surface and soil water recovery due to the vent well construction designs (RUST E&I, 1993). Field respiration measurements were not successfully quantified during this study.

The objective of the bench-scale bioremediation tests was to determine the fuel biodegradation potential of indigenous microorganisms under natural and nutrient-enhanced conditions, both with and without microbial inhibitors. Laboratory bioreactors were used to conduct the biodegradation study. Parameters measured in the laboratory included oxygen utilization, microbial colony forming units (CFUs) from

aerobic plate counts, and total petroleum hydrocarbon (TPH)-DRO concentrations. The bench-scale bioremediation study showed that a significant population of indigenous microorganisms are already present in contaminated soils at the site and that the microbial CFUs were substantially increased with the addition of oxygen. Although bacterial CFUs initially grew more rapidly in the nutrient-amended soils, the peak numbers of CFUs were about the same for both the amended and unamended soils. Some detrimental test control problems were experienced, including ammonia production that resulted in large pH increases. The measured reduction of TPH-DROs was inconclusive during the experiment as well. Based on the SVE pilot test and bench-scale bioremediation test results, RUST E&I concluded that *in situ* bioremediation using bioventing without nutrient amendments appears to be a viable technology for the site. It was further recommended that prior to implementing a full-scale bioventing system, a long-term bioventing pilot test using air injection should be tested at the site (RUST E&I, 1993).

2.1.3 Site Contaminants

The predominant contaminants at Site FT-01 are VOCs and SVOCs associated with petroleum hydrocarbons. Since a wide variety of flammable liquid wastes were once burned at the site, chlorinated solvents, pesticides, and metals are also present in soils and groundwater. Petroleum hydrocarbon DROs are present in the soils at depths ranging from ground surface to greater than 8 feet bgs. The depth to groundwater averages 9.5 to 10 feet bgs in the middle of the site. Soil DRO maximum concentrations of 9,500 mg/kg were detected in soil boring SB-4 at a depth of 0 to 3 feet bgs. Soil samples collected from SB-1 at a depth of 6 to 8 feet contained 6,300 mg/kg of DRO petroleum hydrocarbons. The majority of the groundwater contamination appears confined to the surficial aquifer, which typically extends from 10 to 80 feet bgs.

ES performed a limited site screening soil gas survey in March 1994 to determine those areas with elevated total volatile hydrocarbons (TVH) and oxygen-depleted soils. Soil gas probes and headspace screening on several existing wells were used to accomplish the soil gas survey. Using a portable total hydrocarbon analyzer, soil headspace TVH concentrations ranged from 19 parts per million (ppm) at MW-116 to 1,400 ppm at existing vent well SVE-1. Soil oxygen levels were depleted in the vicinity of the primary burn pit.

2.2 IRP Site SS-15 (POL Depot)

2.2.1 Site Location and History

IRP Site SS-15 is located within OU-1, which includes the entire POL Bulk Fuel Storage Facility (POL Depot) and the Rail Siding Fuel Transfer Facility. This area is located on the southwestern part of the base. Three other IRP sites are found within OU-1, including: IRP Site SS-04, IRP Site OT-05, and IRP Site ST-14. The POL Depot provides storage and transfer of JP-4 jet fuel for Shaw AFB.

The POL Depot currently contains two above-ground fuel storage tanks (700,000 gallon and 525,000 gallon capacity), five 50,000-gallon USTs, nineteen 25,000-gallon USTs, and a network of ancillary fuel transfer piping, filters, and drains used in the facility operations. Two smaller 1,000-gallon USTs were recently excavated and

removed from the facility. The proposed bioventing system will be installed near the site of the 1,000-gallon UST previously located south of Building #112. This area of the POL Depot is shown in Figure 2.3. The 1000-gallon UST was used as a reclaimable fuel tank during cleaning of the adjacent fuel filters. Approximately 100 feet west of the former reclaimable fuel UST is a system of ten 25,000-gallon USTs. These USTs, installed during the 1940's, are the oldest in the POL Depot. Several of the USTs in this group were suspected of leaking. A confirmed leaking UST within this system was the original designation of IRP Site SS-15; however, the base has since included all leaking UST systems in the POL Depot under the Site SS-15 designation. Figure 2.3 shows a partial site plan of the POL Depot with the location of the existing and former USTs, transfer piping, and monitoring wells around the proposed bioventing test area.

Soil contamination within the proposed pilot test area has likely originated from numerous sources, including the former 1,000-gallon reclaimable fuel UST and the USTs and piping located west and south of this tank. Historically, a number of fuel releases (primarily JP-4 jet fuel) have occurred within the POL Depot during its operation. The base estimates that a total of 500,000 gallons have been released since the facility began operating. The largest single spill event occurred when UST #18 was overfilled and 230,000 gallons of JP-4 fuel were released to the ground surface via a tank vent pipe. The remaining quantity of spilled fuel originated from minor spills and at leaking USTs and transfer pipes within OU-1 (Shaw AFB, 1994). As a result of these spills, a significant volume of soil and groundwater beneath the POL Depot and surrounding areas is impacted by petroleum hydrocarbons. A liquid-phase fuel product layer has formed on the capillary fringe and has migrated approximately 800 feet south and southeast of the area defined by the 525,000-gallon above-ground fuel storage tank and piezometer PZ-606 (see Figure 2.3). The proposed bioventing pilot test site will be located at least 100 feet from any areas with measurable liquid-phase fuel product.

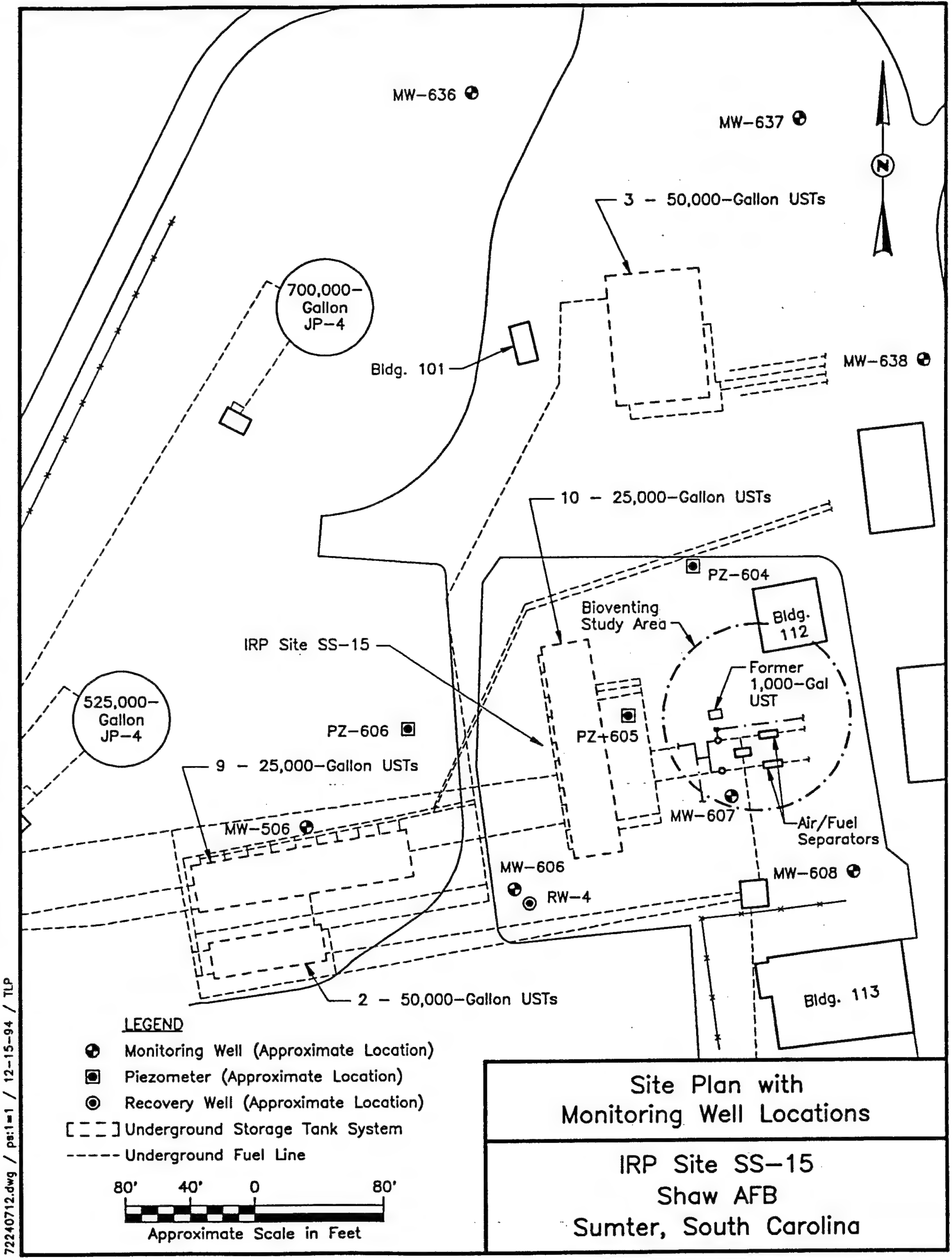
Shaw AFB is currently redesigning and upgrading the POL Depot. The base plans to convert all of the facility jet fuel storage to above-ground tanks. A third above-ground storage tank is planned for construction within the bermed area to provide additional fuel storage capacity. The existing twenty-four USTs and their ancillary piping will be removed from service and abandoned in place by filling the tanks with an inert material. This process was initiated early in 1994 when the USTs were emptied of their contents and removed from service. The base currently does not plan to excavate any of the large USTs or the subsurface piping in the vicinity of the proposed bioventing pilot test area (Shaw AFB, 1994).

2.2.2 Previous Investigations

Operable Unit #1 and the POL Depot have been investigated by multiple IRP contractors. A total of 85 shallow and deep monitoring wells and piezometers have been installed to date to define the extent of groundwater contamination in and around OU-1. Contractors conducting investigations and/or pilot studies at the POL Depot include: Law Environmental, Inc.; International Technology Corporation. (IT); Groundwater Technology, Inc. (GTI); and Geraghty & Miller, Inc.

OH Materials, Inc. (OHM) installed a groundwater/fuel recovery and treatment system at the POL Depot under a 'rapid response' contract. The operating system

Figure 2.3



Site Plan with Monitoring Well Locations

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

PARSONS ENGINEERING SCIENCE, INC.

consists of nine liquid recovery wells located within the zone of liquid-phase product. Each recovery well has a two-pump system. One pump creates a water table cone of depression by pumping only groundwater and the other pump recovers liquid-phase fuel. As of January 31, 1994 a total of 56,281 gallons of fuel had been recovered from the subsurface by this system. The closest recovery well (RW-4) is approximately 200 feet from the proposed bioventing system.

Several remedial pilot studies have been conducted at OU-1 and the POL Depot. Technologies tested and evaluated by the various contractors include *in situ* air sparging, soil vapor extraction, vacuum-enhanced groundwater pumping, and bench-scale bioremediation tests. In some cases, a single technology has been tested by more than one contractor on different parts of the site. None of these pilot tests were performed within a 200-foot radius of the proposed bioventing pilot test site.

2.2.3 Site Contaminants

The majority of contaminants at Site SS-15, and at the POL Depot in general, are petroleum hydrocarbons associated primarily with JP-4 jet fuel. Minor spills of other fuel types, such as AVGAS, are also reported at OU-1. The source(s) of contamination within the proposed bioventing pilot test area are expected to be JP-4 fuels released both from the 1,000-gallon reclaimable fuel UST and the leaking 25,000-gallon USTs located about 100 feet west of this tank.

The RI/FS soil sampling program has been extensive at the POL Depot. Soil sampling results have ranged from nondetectable TPH and VOCs to samples saturated with hydrocarbons in the vicinity of the liquid-phase product plume. The proposed bioventing test site is located about 100 feet north of the northeastern edge of the liquid-phase product plume. Soil sampling results associated with removal of the 1,000-gallon reclaimable fuel UST were not available at the time this work plan was developed. The Shaw AFB Liquids Fuels Maintenance Supervisor (Mr. Ray Alford) reported that shallow soils excavated during the UST removal had a very strong petroleum odor and appeared to be saturated in fuel (Shaw AFB, 1994). Soil samples collected from borings around UST #5 (original IRP Site SS-15 spill area) had detectable concentrations of TPH as Kerosene ranging from 79 mg/kg to 4,900 mg/kg (Geraghty & Miller, 1993).

ES performed a limited site screening soil gas survey at Site SS-15 in March 1994 to determine those areas with elevated TVH and oxygen-depleted soils. Soil gas probes and headspace screening on several existing wells and piezometers were used to accomplish the soil gas survey. Using a portable total hydrocarbon analyzer, soil headspace TVH concentrations ranged from 3,000 parts per million (ppm) at piezometer PZ-604 to 8,000 ppm at piezometer PZ-605. Both of these piezometers are in close proximity to the proposed bioventing pilot test area (see Figure 2.3). Closer to the liquid-phase product plume, monitoring wells MW-506 and MW-606 both had TVH headspace readings greater than 20,000 ppm. A soil gas probe advanced into the former 1,000-gallon UST excavation yielded TVH readings of 400 ppm (5-foot depth) and 12,000 ppm (10-foot depth). Soil oxygen levels were depleted at each of these test points, with oxygen concentrations ranging from 0 to 3 percent.

2.3 Geologic and Hydrogeologic Characterization

2.3.1 Regional Geology and Hydrogeology

Shaw AFB is located in the central Coastal Plain physiographic province of north-central South Carolina. Sediments beneath the base are characterized as a thick sequence of unconsolidated, interbedded sands, silts, and clays that dip and thicken toward the southeast. The subsurface stratigraphy originated primarily from marine and fluvial depositional processes. These interbedded sediment layers are grouped into regional formations and aquifers based on lithologic and water quality characteristics. Three primary aquifer systems underlie Shaw AFB. These primary aquifer systems are (in descending order) the shallow water table aquifer, the Black Creek Aquifer, and the Middendorf Aquifer. Shallow groundwater discharges to nearby streams as well as recharging the underlying Black Creek aquifer through leakage. Groundwater is encountered at depths ranging from about 10 feet bgs on the east side of the base to greater than 50 feet on the west side of the base.

Surficial soils around the base, while generally sandy and highly permeable at shallow depths, tend to be poorly sorted and often contain discontinuous lenses of clay and gravel. The surface topography at the base is gently sloping between interstream divides but it has large geomorphic relief within the eroded stream valleys. The western portion of the base is located near the eastern edge of the High Hills of Santee, a remnant geomorphic land surface (terrace) that has an average elevation approximately 200 feet greater than the surrounding area. Topographically, land surface at the base slopes gently from the northwest toward the southeast. The maximum elevation on the northwest corner of the base is approximately 360 feet above mean sea level (msl), compared to 200 feet msl on the southeast corner of the base.

2.3.2 Local Lithology and Hydrogeology: Site FT-01

The shallow stratigraphy at Site FT-01 consists of sands, silts, and clays of the Duplin Formation. The Duplin Formation forms the surficial, unconfined aquifer throughout the region. Soil boring logs indicate that the Duplin Formation extends to an average depth of 80 feet bgs at Site FT-01. The upper portion of this formation consists of well-graded to poorly-graded sands with approximately 15 percent silts and clays. The silt and clay content tends to increase with depth within the Duplin Formation. A relatively thin clayey silt layer was identified in several borings at depths ranging from 3 to 5 feet bgs to 4 to 9 feet bgs. This discontinuous clayey silt layer was not present in all of the borings and is most prominent near the middle and eastern sections of the site.

The water table occurs at an average depth of about 9.5 to 10 feet bgs near the center of Site FT-01. A perched water table is reported to occur from about 3.5 to 5 feet bgs within the clayey silt unit, while unsaturated sediments occur below this zone from about 5 to 9.5 feet bgs. The lateral extent of the clayey silt unit and the perched water table is not completely defined. Additionally, it is not known if the perched water table occurs only on a seasonal basis. ES measured water levels at several wells on March 16, 1994. Water levels surrounding the burn pit area ranged from 11.54 feet bgs at MW-116 to 11.53 feet bgs at MW-112. Within the center of the burn pit, well SVE-1 (screened from 2.87 to 8.17 feet bgs) had a water level of 4.31 feet bgs,

indicating an influence from the perched water table. Soil gas probes installed by ES in the middle of the primary burn pit encountered saturated soils (perched water) at a depth of 3.5 feet bgs. Locally, shallow groundwater flows generally southeast to a discharge zone at Long Branch.

Two 4-inch diameter horizontal air injection wells and four vapor monitoring points (MPs) will be installed above the permanent water table as part of the pilot study. The air injection wells will be screened in the unsaturated zone below the clayey silt layer containing the perched water table. Existing groundwater monitoring wells MW-116 and MW-111 and existing SVE well SVE-1 will be used as soil vapor MPs if sufficient screen is exposed above the water table during the field testing activities. The existing vertical vent well (SVE-1) and horizontal vent well (HVE-1) installed by RUST E&I are not adequately designed for use as air injection vent wells for the bioventing pilot study. The four additional soil vapor MPs will be installed at multiple depths to study the subsurface oxygen distribution pattern during the pilot test. The screened intervals of the MPs will placed so that soil gas can be monitored above and below the perched water table zone (if present).

2.3.3 Local Lithology and Hydrogeology: Site SS-15

The shallow stratigraphy at Site SS-15 and the POL Depot consists of sands, silts, and clays of the Duplin Formation. The Duplin Formation forms the surficial, unconfined aquifer in this area. Soil boring logs indicate that the Duplin Formation extends to average depths of 70 to 80 feet bgs at Site SS-15. The saturated thickness of the surficial aquifer ranges from 15 to 30 feet below the POL Depot. Unconsolidated sediments above the water table consist mainly of reddish-brown to yellowish-red coarse-grained sands and gravel with discontinuous lenses of sandy silt and clayey sand. The silt and clay content tends to increase with depth within the Duplin Formation. Shallow sediments in this area reportedly have high concentrations of iron.

The water table occurs at depths of approximately 42 to 45 feet bgs in the middle of the POL Depot. ES collected water levels from MW-506, MW-606, and PZ-604 in March, 1994 to confirm these depth(s) to groundwater around the proposed bioventing test site. Perched groundwater above the permanent water table zone has not been reported by previous contractors. Seasonal water table fluctuations of 2 feet are common. Groundwater flow in the POL Depot area is generally toward the south, although flow components toward the southeast and southwest are reported for the surrounding areas. The primary discharge zone of the water table aquifer is leakage into the underlying Upper Black Creek Aquifer. The average linear velocity of groundwater in the surficial aquifer below the POL Depot is 388 feet per year (Geraghty & Miller, 1993).

3.0 SITE SPECIFIC ACTIVITIES

This section describes the proposed locations of the air injection vent wells and vapor monitoring points (MPs) at the proposed bioventing test sites. Soil sampling procedures and the blower configurations that will be used to inject air (oxygen) into contaminated soils are also discussed in this section. The conceptual bioventing test design and field sampling activities described in this section will be applied to both

bioventing test sites. Minor modifications to the vent well and MP configurations will be necessary to suit specific conditions at each site.

Pilot test activities will target unsaturated soils remediation. Existing site monitoring wells and/or piezometers will be used as supplemental soil vapor MPs if there is sufficient screened interval across the water table. Additionally, existing uncontaminated monitoring wells or piezometers that have a portion of their screened interval above the water table may be used to measure the composition of background soil gas. If existing groundwater monitoring wells or piezometers do not meet these criteria, then a background vapor MP will be installed at each test site upgradient of the study area.

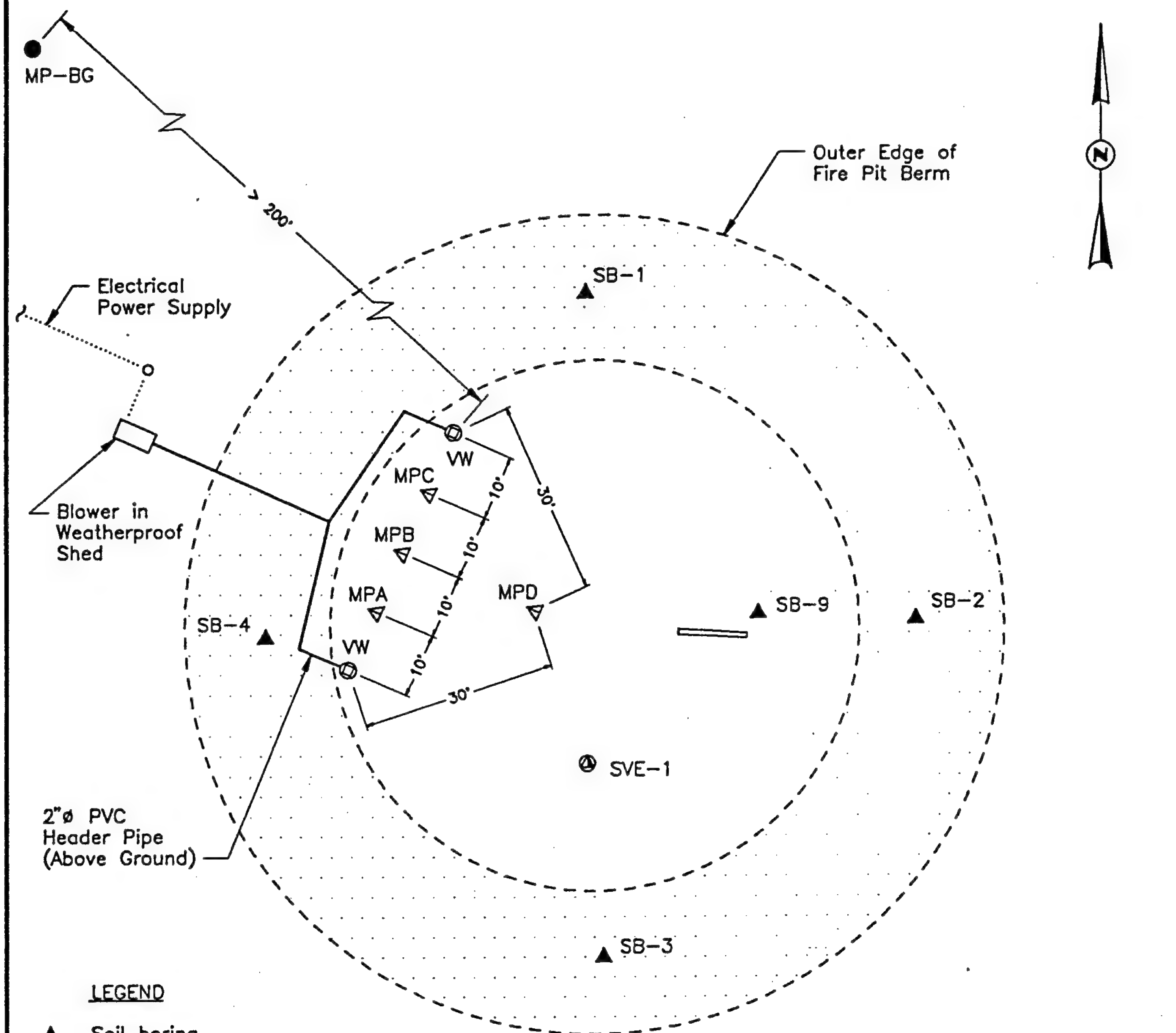
3.1 Bioventing Test Design For Site FT-01

A general description of criteria for siting the soil venting (air injection) wells and vapor MPs are included in the attached protocol. The system design for Site FT-01 is modified from the standard protocol in that two 4-inch vent wells will be installed on 40-foot centers and each vent well may slightly penetrate the water table. Considering the shallow depth of contamination of unsaturated soils at this site (< 10 feet bgs), the soil lithology, and the venting well configurations and operations required to accommodate shallow water table conditions, the radius of oxygen influence for each air injection vent well is expected not to exceed 30 feet. Figure 3.1 shows the proposed locations of the air injection vent wells and soil vapor MPs at the site.

Both 4-inch air injection vent wells will be installed in contaminated soils just above the water table. The estimated completion depth of both vent wells is 10 feet bgs, with the screened intervals from 5 to 10 feet bgs. The final depths may be modified slightly based on field conditions encountered at the time of system installation. A key factor in bioventing this site is designing the vent wells for the presence (or absence) of the clayey silt layer causing the perched water table. The vent wells will be constructed so that their screened intervals are positioned below the perched water table zone. An extended bentonite seal will be used in the vent well borehole to isolate the screen and to prevent (or minimize) perched groundwater from flowing into the screen and infiltrating the underlying unsaturated soils. Short-circuiting of injected air with the ground surface is more likely to occur if the vent wells are screened above the shallow perched water table.

Based on site investigation data, the air injection vent wells and vapor MPs will probably be installed within the primary burn pit. This area is the most contaminated and is expected to have an average TPH concentration exceeding 5,000 mg/kg in unsaturated soils. The proposed orientation of the vent wells and MPs on the northwest side of the primary burn pit is shown in Figure 3.1. The final locations of these wells may vary slightly from the locations shown in Figure 3.1. If the perched water table in this area is expected to hinder bioventing operations, the vent wells and MPs may be relocated away from the primary burn pit altogether. A limited soil boring program may be initiated to delineate the occurrence of the perched groundwater and to facilitate siting the vent wells. Alternatively, the secondary burn pits around the site may be considered for bioventing installations if necessary.

Four MPs will be located within a 30-foot radius of the air injection vent wells. As depicted in Figure 3.1, three of the MPs will be placed in a straight line on 10-foot



LEGEND

- ▲ Soil boring.
- ● Proposed background monitoring point.
- △ Proposed soil vapor monitoring point.
- Proposed air injection vent well.
- Approximate location of vertical SVE well (RUST E & I).
- Approximate location of horizontal SVE well (RUST E & I).
- Approximate location of former fire ring berm.

Map Source: RUST E & I (1993).

25' 10' 0 25'

Approximate Scale in Feet

Note:

1. Final location of bioventing system may vary from the location depicted above.

Proposed Vent Well and Monitoring Point Locations

IRP Site FT–01
Shaw AFB
Sumter, South Carolina

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ES ENGINEERING–SCIENCE

centers between the air injection vent wells. The fourth MP will be placed 30 feet east or southeast of the air injection vent wells. An effort will be made to use an existing monitoring well to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources (i.e. organic layers) or abiotic reactions are contributing to oxygen uptake during the *in situ* respiration tests. Existing wells MW-111 and/or MW-116 may be suitable for this purpose. If no suitable existing well is available, a background MP will be constructed in clean soils upgradient of the site.

Existing wells may be temporarily converted to vapor MPs for conducting respiration tests and air permeability tests. At Site FT-01, existing vent well SVE-1 may be utilized for this purpose since this well has about 1.5 feet of screen above the water table surface. Soils around this well have the greatest potential of being oxygen depleted and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during full-scale operations. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document.

3.1.1 Vent Well Installations

A drilling rig equipped with 10-inch (nominal diameter) hollow stem augers will be used to advance the boreholes for the vent wells. Both air injection vent wells will be constructed of 4-inch (nominal I.D.) Schedule 40 PVC, with 5 feet of 0.02-inch slotted "high-yield" screens. The vent well screens will be set to a maximum depth of 10 feet bgs. The "high-yield" well screens have more open area per linear foot than conventional monitoring well screens, thereby reducing backpressure head losses and improving air exchange with the formation. A vent well construction schematic is provided in Figure 3.2.

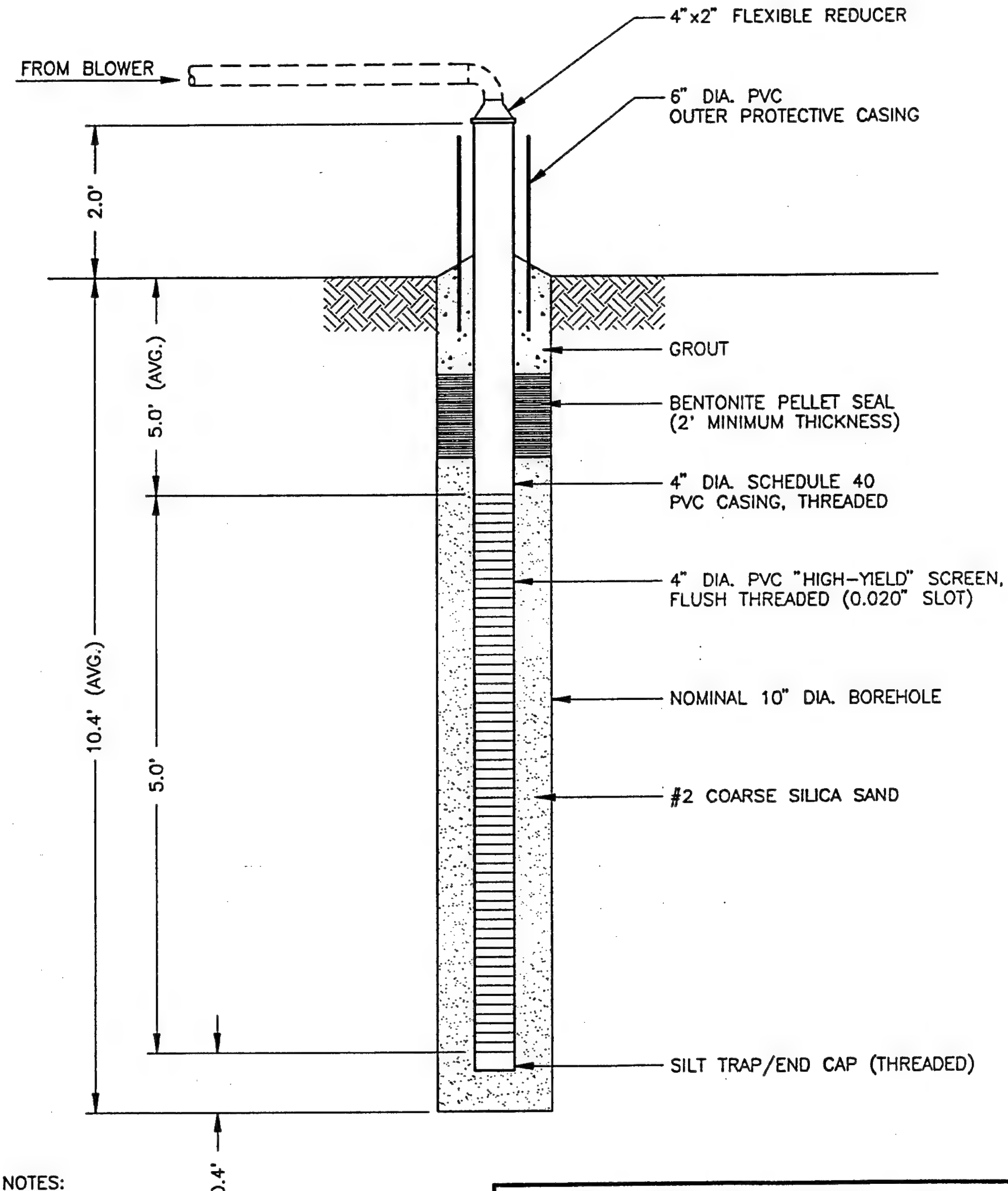
A 5-foot PVC casing will be installed in the borehole above the screened section. Flush-threaded PVC casings and screens will be used for vent well construction up to the manifold pipe connection. A filter pack of coarse #2 silica sand will be placed entirely around the screened interval of the borehole and extended to approximately 6 inches above the uppermost screen slot. A 2-foot bentonite pellet seal will then be installed to seal the borehole and isolate the screen. Cement grout will be placed in the borehole annulus above the bentonite seal to finish the installation. Each vent well will be connected to a 2-inch, above-ground manifold pipe attached to a header pipe at the blower shed.

3.1.2 Vapor Monitoring Point Installations

A typical multi-depth vapor MP installation for Site FT-01 is shown in Figure 3.3. Boreholes for the shallow MPs will be advanced using either hand augers or a drilling rig. The MPs will be constructed of 0.5-inch PVC casings and screens and equipped with an air-tight gas ball valve set in a flush-mount manhole cover. Thermocouples will be installed at several MPs to measure soil temperature. The feasibility of using multi-depth screens for each MP will be determined by site conditions encountered during the MP installation. The water table depth, zones of perched groundwater, and the relative depth of fuel contamination are factors in placing the MP screened intervals.

If soil borings identify two unsaturated zones separated by a perched water table, the MPs will be constructed using multi-depth screened intervals as shown in Figure 3.3.

Figure 3.2



NOTES:

1. Drawing is not to scale.
2. Header pipe from blower (dashed line) will not be installed during well construction.
2. When not in use, the vent well will have a locking inner cap and slip cap for the outer protective casing.

Proposed Air Injection Vent Well Construction

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

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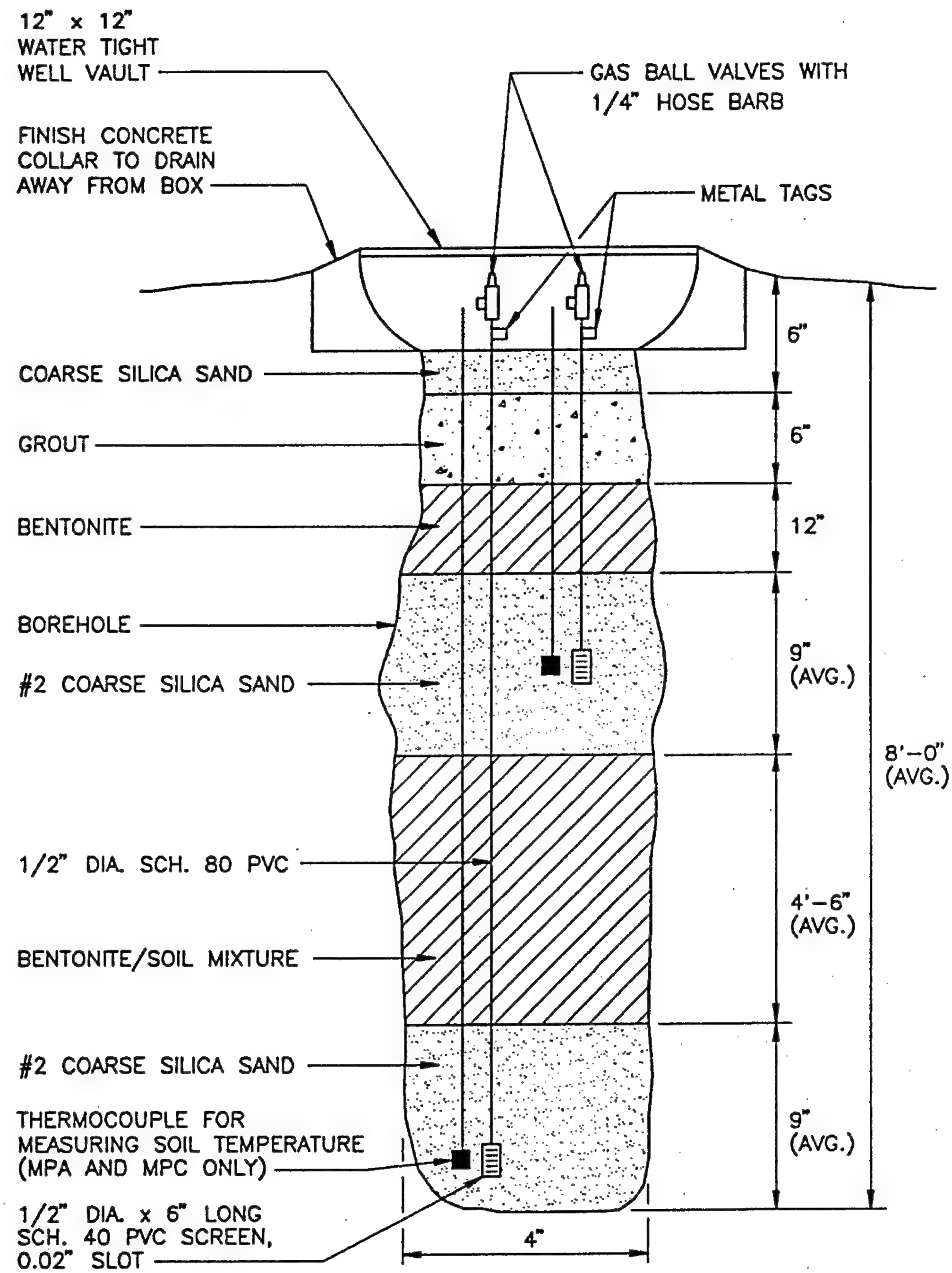
Figure 3.3



Notes:

1. Final depths of monitoring point screens will depend on water table depth at time of installation. Multi-depth screens may not be installed at each monitoring point location.

2. Seasonal perched water table may be present from 3.5' to 5' below ground surface.

DRAWING IS NOT TO SCALE

Typical Monitoring Point
Construction Detail

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

72240715.dwg / 1=1 / 4-25-94 / TLP

ES ENGINEERING-SCIENCE

In this case, one of the MP screens will be installed approximately one foot above the perched water table surface (approximately 2.75 feet bgs) and the second screen will be installed below the perched groundwater zone but above the permanent water table (approximately 8 feet bgs). In the absence of perched groundwater the shallow MP screen will be installed slightly deeper.

Soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at the final screened interval at each MP location. Multi-depth monitoring, if applicable, will confirm that the entire soil profile is receiving oxygen and will be used to measure fuel biodegradation rates at both screened depths. The annular space between multi-depth screens will be sealed with bentonite to isolate the monitoring intervals. Data from the background vapor MP will also be used to determine if abiotic or non-fuel oxygen uptake is occurring in the soils. Additional details on vapor monitoring point construction are found in Section 4 of the protocol document.

3.2 Bioventing Test Design For Site SS-15

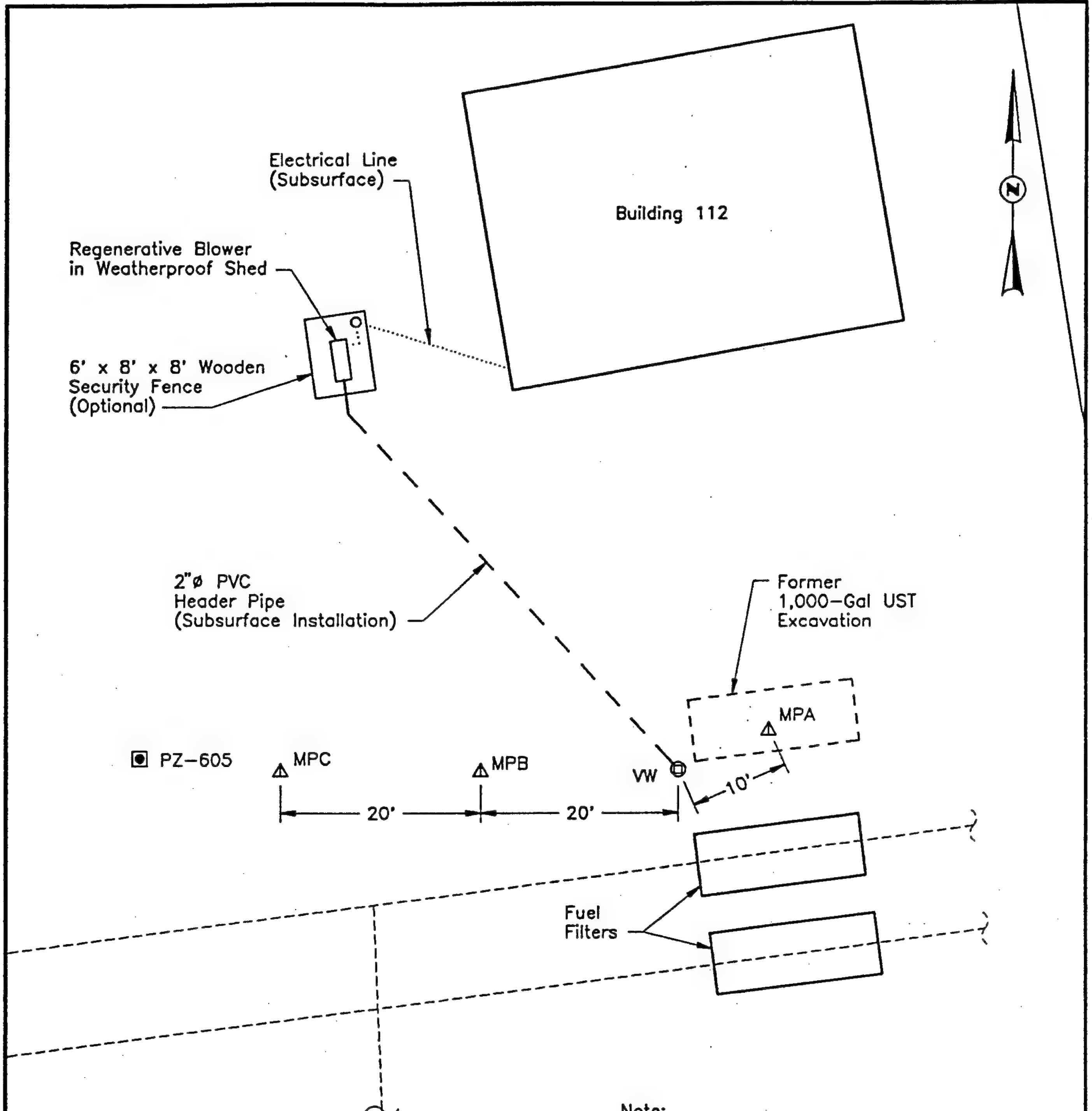
The bioventing system design for Site SS-15 conforms to the standard protocol in that a single air injection vent well and multi-depth MPs will be used. Considering the increased depth of contamination of unsaturated soils at this site (>30 feet bgs), the soil lithology, and the venting well configuration and operation, it is feasible that the radius of oxygen influence for the single air injection vent well may exceed 50 feet. Figure 3.4 shows the proposed locations of the vent well and soil vapor MPs at the site.

The 4-inch air injection vent well will be installed in contaminated soils to a depth several feet above the water table. The estimated completion depth of the vent well is 42 feet bgs. The screened interval will extend from about 12 to 42 feet bgs. The final vent well design may be modified slightly based on field conditions encountered at the time of system installation. Short-circuiting of injected air with the ground surface is more likely to occur at this site if the vent well is screened less than 10 feet bgs.

The air injection vent well and vapor MPs will be installed in the immediate vicinity of the former 1,000-gallon reclaimable fuel UST. The vent well will be installed outside the former UST excavation. Generally, this entire area has been impacted by petroleum hydrocarbons from multiple sources and is expected to have elevated TPH concentrations in unsaturated soils. The proposed orientation of the vent well and MPs is shown in Figure 3.4. The final locations of these wells may vary slightly from the locations shown in Figure 3.4.

Three soil vapor MPs will be installed within a 40-foot radius of the air injection vent well. As depicted in Figure 3.4, two of the MPs will be placed in a straight line on 20-foot centers between the vent well and the UST system west of the vent well. Soil TPH concentrations are expected not to decrease in this direction since several of the 25,000-gallon USTs in this system were suspected of leaking. The third vapor MP will be placed within the former 1,000-gallon UST excavation approximately 10 to 15 feet east of the air injection vent well. Existing piezometer PZ-605 will also be converted to a vapor MP. This 2-inch piezometer has approximately six feet of screen above the water table and will be used to monitor soil gas at a radius of about 55 feet from the vent well.

Figure 3.4



Note:

1. Final location of bioventing system may vary from the location depicted above.

LEGEND

- Piezometer (approximate location).
- ----- Underground fuel line (abandoned).
- Proposed air injection vent well.
- Proposed soil vapor monitoring point.

15' 10' 5' 0 15'

Approximate Scale in Feet

Proposed Vent Well and Monitoring Point Locations

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

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An effort will be made to use an existing piezometer or monitoring well to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources (i.e. organic layers) or abiotic reactions are contributing to oxygen uptake during the *in situ* respiration tests. Existing wells MW-636 and/or MW-637 may be suitable for this purpose because they are upgradient of the plume originating from the POL Depot. If no suitable existing well is available, a background MP will be constructed in clean soils upgradient of the site. Alternatively, an existing well on another part of the base with similar soils and a deep water table may be used as a control site to monitor background conditions.

Existing monitoring wells and piezometers may be temporarily converted to vapor MPs for conducting short-term respiration tests and air permeability tests. At Site SS-15, existing piezometers PZ-604 and PZ-605 and well MW-607 will be considered for this purpose. Soils around these points are known to be oxygen-depleted and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during full-scale operations. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document.

3.2.1 Vent Well Installation

A drilling rig equipped with 10-inch (nominal diameter) hollow stem augers will be used to advance the borehole for the vent well. The air injection vent well will be constructed of 4-inch (nominal I.D.) Schedule 40 PVC with 30 feet of 0.02-inch slotted "high-yield" screens. The vent well screen will be set to a maximum depth of 42 feet bgs. A vent well construction schematic is provided in Figure 3.5.

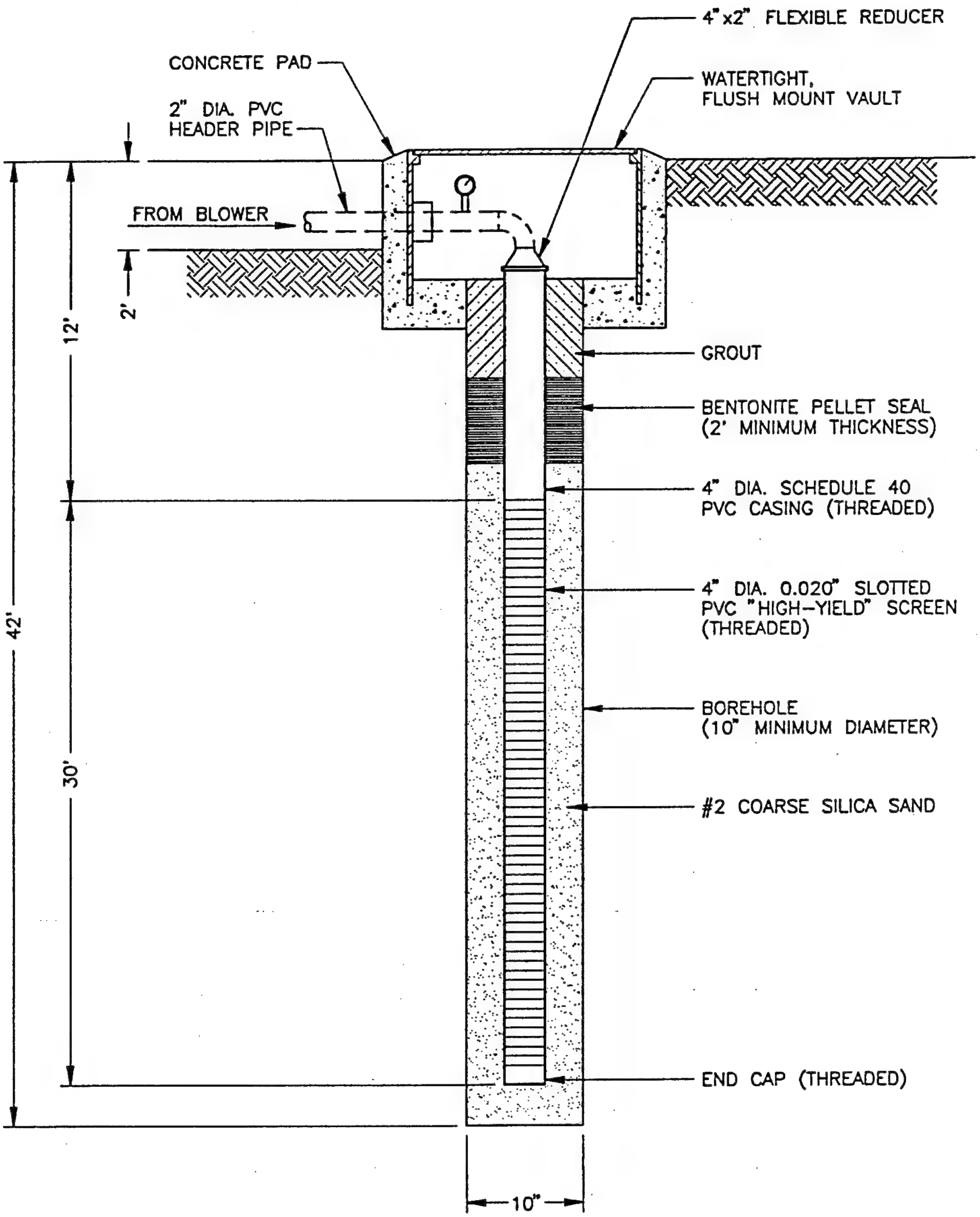
A 12-foot PVC casing will be installed in the borehole above the screened section. Flush-threaded PVC casings and screens will be used for vent well construction up to the header pipe connection. A filter pack of coarse #2 silica sand will be placed entirely around the screened interval of the borehole and extended to approximately 1-foot above the uppermost screen slot. A 2-foot bentonite pellet seal will then be installed to seal the borehole. Cement grout will be placed in the borehole annulus above the bentonite seal to finish the installation. A flush-mount locking well vault will be installed to protect the wellhead. The vent well will be connected to a 2-inch, subsurface header pipe attached to the blower.

3.2.2 Vapor Monitoring Point Installations

A typical multi-depth vapor MP installation for Site SS-15 is shown in Figure 3.6. Boreholes for these MPs will be advanced using a drilling rig. The MPs will be constructed of 0.75-inch PVC casings and screens and equipped with an air-tight gas ball valve set in a flush-mount manhole cover. Thermocouples will be installed in several MPs to measure soil temperature. A minimum of three multi-depth screened intervals will be installed at each MP location to monitor vertical variations in soil gas composition. The water table depth, soil lithologies, and zones of fuel contamination are factors in placing the MP screened intervals. The actual MP screened depths may vary from those shown in Figure 3.6 based on these factors.

Soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at the final screened interval of each MP. Multi-depth screened intervals placed throughout the contaminated soil column will confirm that the entire soil profile is receiving

Figure 3.5



NOTES:

1. Drawing is not to scale.
2. Header pipe from blower (dashed line) will not be installed during well construction.

Proposed Air Injection Vent Well Construction

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

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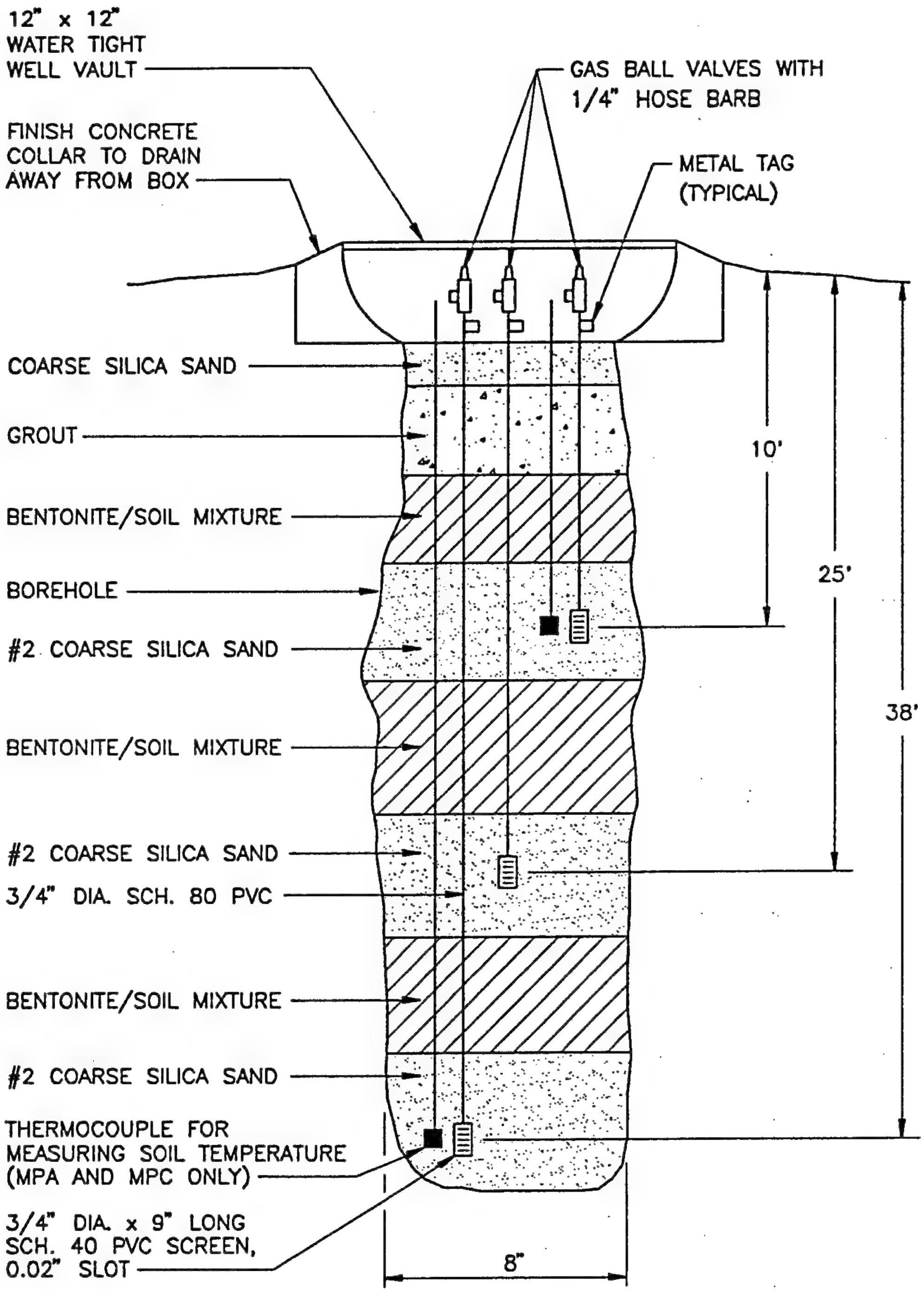
Figure 3.6



DRAWING IS NOT TO SCALE

Typical Monitoring Point
Construction Detail

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

Note:

1. Water table depth is approximately 42 feet below ground surface at test site.

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ES ENGINEERING-SCIENCE

oxygen and will be used to measure fuel biodegradation rates at each screened depth. The annular space between multi-depth screens will be sealed with bentonite and clean soil cuttings to isolate the monitoring intervals. Data from the background vapor MP will also be used to determine the relative natural diffusion of atmospheric oxygen into the shallow soils. Additional details on vapor monitoring point construction are found in Section 4 of the protocol document.

3.3 Soil and Soil Gas Sampling

Soil and soil gas sampling procedures described in this section will be used for both bioventing sites. Any site-specific exceptions to these procedures are described as necessary.

3.3.1 Soil Sampling

Three soil samples will be collected from the pilot test area during the installation of the vent wells and MPs. Sampling procedures will generally follow those outlined in the protocol document by using a split spoon or Shelby tube soil sampler. Samples will be collected and screened for TVH at 3-foot to 5-foot intervals. At Site FT-01, soil samples will be collected from the MPs with a hand auger if a drill rig is not used.

One of the three soil samples will be collected from the most contaminated interval of the vent well. Additionally, one soil sample will be collected from the interval of highest apparent contamination in two of the borings for the MPs. Soil samples will be analyzed for TRPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, total Kjeldahl nitrogen (TKN), and phosphates. A sample will also be collected from uncontaminated soils at the background MP for TKN analysis.

Samples will be collected from the MPs by hand augering or split-spoon sampling to the desired sampling depth and transferring the soil sample directly to the sample jars. A PID or total hydrocarbon vapor analyzer (see protocol Section 4.5.2.) will be used to insure that breathing zone levels of volatiles do not exceed 1 part per million by volume (ppmv) while conducting soil borings and to screen soil samples for relative fuel contamination. Soils from the most contaminated interval of the MPs and vent wells will be submitted for laboratory analyses. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in protective plastic, and placed in an ice chest for shipment. A chain of custody form will be filled out and the ice chest shipped to PACE Laboratory in Huntington Beach, California for analysis. This laboratory has been audited by the U.S. Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.3.2 Soil Gas Sampling

A total hydrocarbon analyzer (see protocol document, Section 4.5.2) will be used during drilling activities to screen sample intervals for fuel contamination. Once the vent well and MPs are installed and adequately purged, soil gas samples will be collected using SUMMA[R] canisters. Three SUMMA[R] canister soil gas samples will be collected, one from the most contaminated vent well and one each from the MPs closest to and furthest from the most contaminated vent well. Quantitative soil gas samples will be used to predict potential air emissions, to determine the reduction of BTEX and TVH during the extended test, and to detect potential migration of these vapors from the source area.

Soil gas samples will be placed in a small box and packed with foam pellets for protection during shipment. Samples will not be placed on ice to prevent condensation of hydrocarbon compounds. A chain-of-custody form will be completed and shipped with the samples to the Air Toxics, Inc. laboratory in Folsom, California. The soil gas samples will be analyzed for BTEX compounds and TVH.

3.3.3 Handling of Waste Soils

Contaminated cuttings from all soil borings and any remaining waste soils will be collected in a DOT-approved 55-gallon metal drum. The drums will be labeled, sealed, and then placed in a designated Shaw AFB waste material storage area. These waste soils will become the property of Shaw AFB and will be analyzed, handled, and disposed of in accordance with the current base procedures for ongoing remedial investigations. This project is expected to generate approximately ten to twelve 55-gallon drums of waste soils.

During the initial site visit, the base point of contact instructed ES on the drill rig decontamination area. A semi-permanent decontamination area was constructed by a drilling contractor involved in a long-term drilling project at the base. Drilling rigs used for the bioventing system installations are allowed to use this decontamination area on a short-term basis. Decontamination wastes generated by this process will be handled by the base.

3.4 Blower Systems

The permanent blower systems used for extended testing at these sites will likely consist of a 1-HP Gast Model R4110-2 regenerative blower equipped with an explosion-proof motor and power switch. This blower produces an open flow of 92 scfm, and 20 scfm at 51 inches of water pressure. Each blower will be installed in a locking, weatherproof box. The blower system at Site SS-15 may also be equipped with an optional noise-dampening muffler installed on the pressure relief exhaust valve to reduce excessive noise around Building #112. Figures 3.7 and 3.8 show schematics of the blower system and instrumentation for Site FT-01 and Site SS-15, respectively.

The maximum power requirement anticipated for this pilot test is a 230-volt, single-Phase, 30 Amp service. The blower will be wired to a starter and 230-volt, single-phase circuit breaker equipped with two standard 115-volt receptacles. In the event that 230-volt power is not available, the blowers can be wired to a 115-volt, single-phase, 30-amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements. As a safety precaution at Site SS-15, it is necessary that the blower motor and starter be explosion proof. Additionally, the cable running to the outlet near the breaker box will be explosion proof. The circuit-breaker box shall be located 5 feet above the ground surface so that all non-explosion proof connections are above the hazardous area. A qualified electrician will complete these explosion-proof connections.

If electrical power is not readily available for installation and operation of the permanent blower, a 1-HP rotary-vane blower (Gast model 2067-P106) capable of injecting 16 scfm at 2 psi will be used to inject air for the initial air permeability tests. Initial testing may demonstrate that more (or less) pressures and air flows are required

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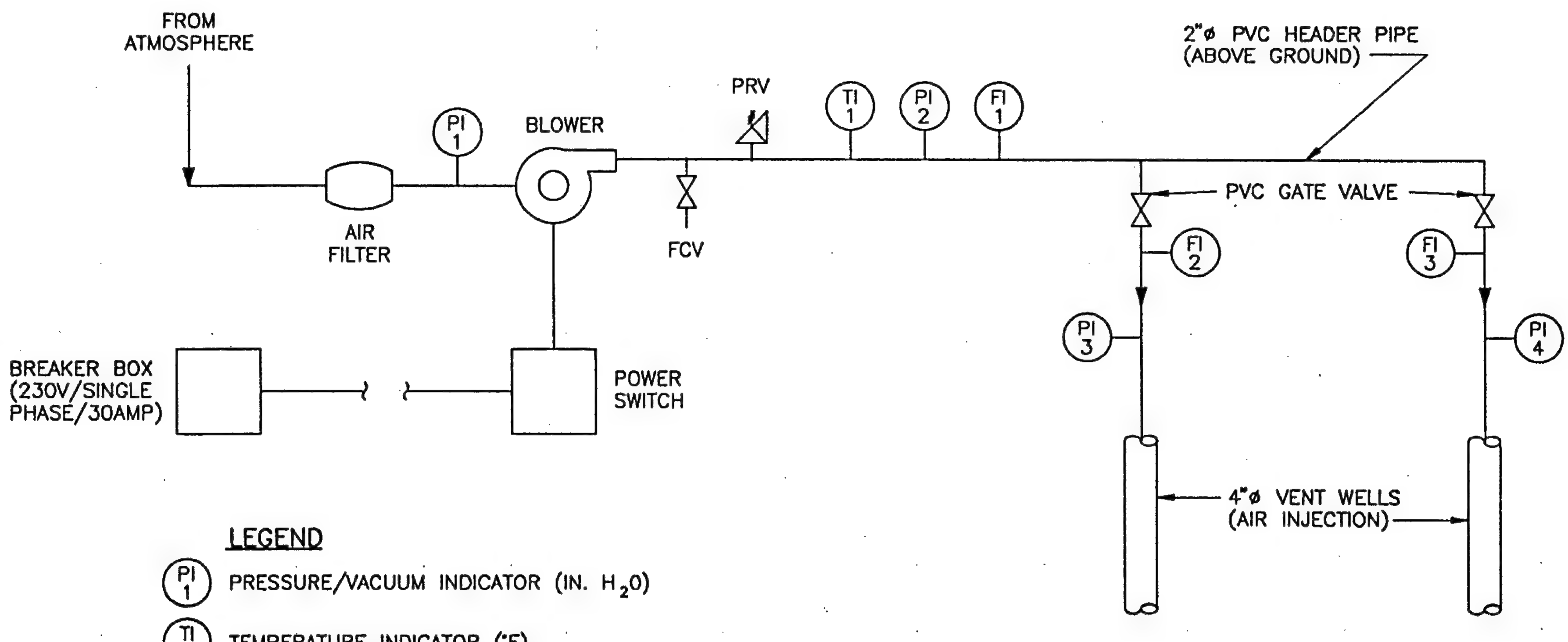

DRAWING IS NOT TO SCALE

LEGEND

- PI 1 — PRESSURE/VACUUM INDICATOR (IN. H_2O)
- TI 1 — TEMPERATURE INDICATOR (°F)
- FI 1 — AIR FLOW MEASURING PORT
- FCV — FLOW CONTROL PRESSURE RELIEF VALVE (MANUAL)
- PRV — PRESSURE RELIEF VALVE (AUTOMATIC)

NOTE: Blower diagram shown is for permanent installation for extended testing.

Blower System Instrumentation Diagram for Air Injection

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

Figure 3.7

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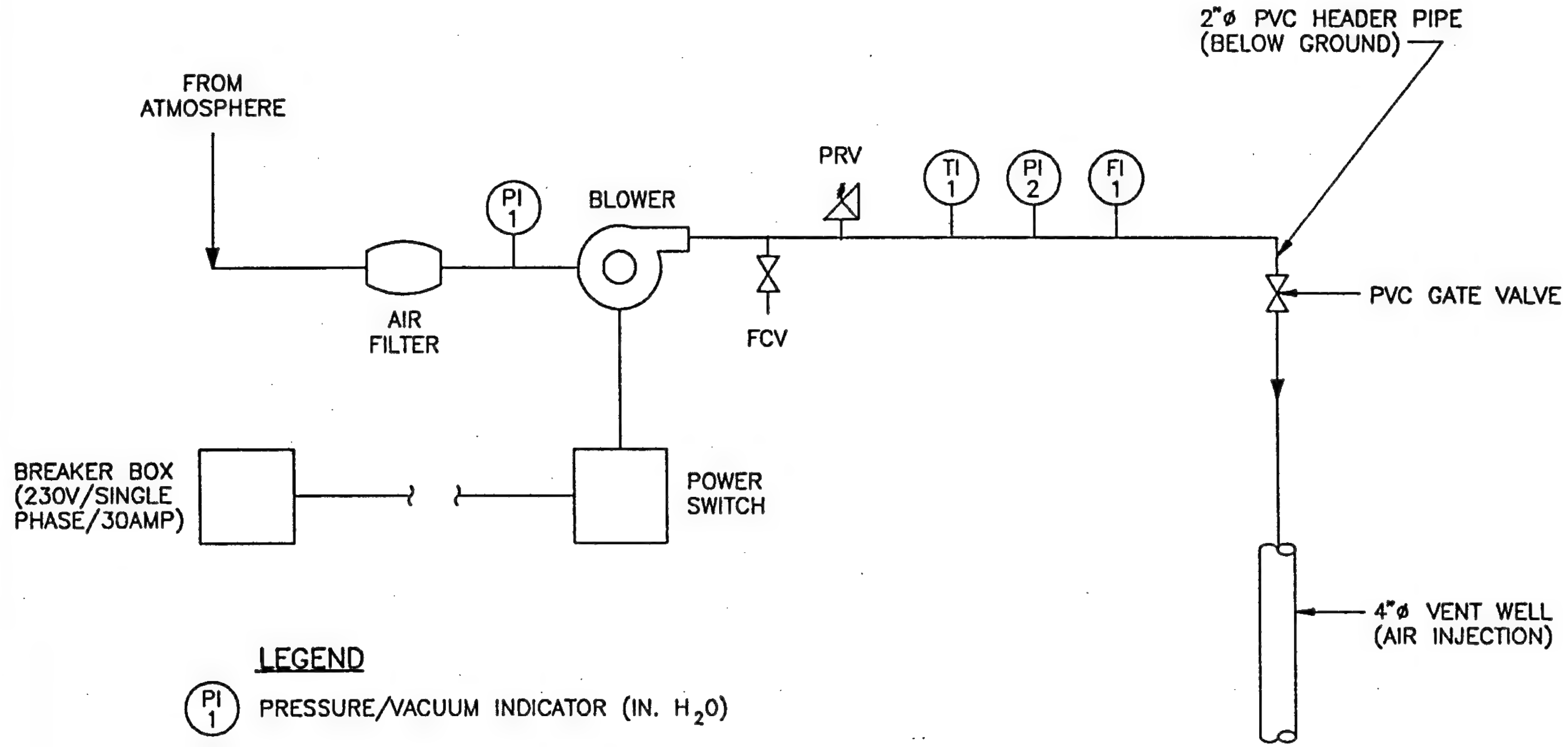

LEGEND

- PI 1 — PRESSURE/VACUUM INDICATOR (IN. H_2O)
- TI 1 — TEMPERATURE INDICATOR (°F)
- FI 1 — AIR FLOW MEASURING PORT
- FCV — FLOW CONTROL PRESSURE RELIEF VALVE (MANUAL)
- PRV — PRESSURE RELIEF VALVE (AUTOMATIC)

NOTE: Blower diagram shown is for permanent installation for extended testing.

DRAWING IS NOT TO SCALE

Blower System Instrumentation Diagram for Air Injection

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

at each site to supply oxygen throughout the test area soil column, in which case the blower size will be adjusted for extended testing.

3.5 *In Situ* Respiration Tests

The objective of the *in situ* respiration tests is to determine the rate at which indigenous soil bacteria will degrade petroleum hydrocarbons when stimulated with oxygen-rich soil gas. Respiration tests will be performed at every MP where bacterial biodegradation of hydrocarbons is indicated by low oxygen levels and elevated carbon dioxide concentrations in soil gas. Air will be injected into each MP screened interval containing low levels (<10%) of oxygen. A 10 to 15 hour injection period will be used to completely oxygenate the surrounding contaminated soils. During the air injection process, a 4% to 6% mixture of inert helium will be injected into the MPs to use as a tracer for potential MP leaks.

If the initial oxygen concentration at the uncontaminated, background MPs is less than 18%, air will also be injected into these MPs to determine if non-fuel or abiotic oxygen uptake is a factor at each site. Shallow soils at Shaw AFB reportedly have elevated iron concentrations. Abiotic oxygen utilization due to iron fixation may be a factor that affects the respiration tests.

At the end of the air injection period, the air supply will be cut off, and oxygen, carbon dioxide, TVH, and helium concentrations will be monitored at regular intervals for the following 24 to 48 hours. The respiration test will continue until oxygen levels have declined at least 5% or, if time permits, until all of the oxygen is consumed. The decline in oxygen and increase in carbon dioxide concentrations measured during the respiration tests will be used to estimate rates of bacterial degradation of TPH in the soils.

3.6 Air Permeability Tests

The objectives of the air permeability tests are to determine soil permeability and the extent that subsurface soils can be oxygenated using one air injection vent well. Air will be injected into the 4-inch air injection vent well using the blower unit. Pressure responses will be measured at each MP and the surrounding monitoring wells using Magnehelic and/or digital manometer pressure gauges. Oxygen will also be monitored in the MPs to determine the radius of oxygen influence achieved during air injection. The air permeability test at each site is expected to last between 2 to 6 hours. Air injection will continue until relative steady-state pressures are achieved in those MPs with a pressure response.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. No deviations from the established testing protocol are anticipated. The only foreseen exceptions to field testing protocol procedures are the possible use of existing wells for use as a vapor MP or as a background monitoring point. One exception to the typical test design presented in the protocol document is the installation of two vent wells at Site FT-01. This design is necessary to maximize the radius of oxygen influence throughout the test area and to minimize potential short-circuiting of air at the ground surface. Air flow rates to the individual vent wells can then be reduced without

affecting the test results. The vent well screens may also penetrate the water table at Site FT-01.

Soil borings for vapor MP installations may be advanced using a hand auger at Site FT-01. In this case, the typical borehole diameter for each monitoring point will be approximately 4 inches, as illustrated in Figure 3.3.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support is needed prior to the arrival of a drilling contractor and the Engineering-Science test team:

- Confirmation of regulatory approval and permitting for the pilot tests.
- Assistance in obtaining a digging permit at the bioventing sites.
- A breaker box mounted to a temporary utility pole on each test site which can supply 230-volt, single-phase, 30 amp electrical service. Alternatively, the blower can be powered by 115-volt, single-phase, 30 amp electrical service if 230-volt service is not readily available at the site. The circuit breaker box should be located five feet above the ground and should include two 115-volt receptacles to support ancillary testing equipment.
- Provide any paperwork required to obtain gate passes and security briefings for approximately three Engineering-Science employees and three drilling contractors. Vehicle passes will be needed for three trucks.

During the initial two-week pilot tests the following base support is requested:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- A decontamination area for the drilling rig.
- Accept responsibility for soil cuttings from vent well and monitoring point borings including any drum sampling to determine hazardous waste status.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the one-year extended pilot tests:

- Check the blower system at each site once a week to ensure that it is operating and to record the air injection pressures and temperatures. Engineering-Science will provide a brief training session and an O&M checklist for this procedure.
- Notify Mr. Grant Watkins, Engineering-Science, Inc., Cary, North Carolina (919) 677-0080; or Mr. Doug Downey, Engineering-Science, Inc. Denver (303) 831-8100; or Capt. Rick Mestan of AFCEE (210) 536-4361 if the blower or motor stop operating.
- Arrange site access and passes for an Engineering-Science technician to conduct *in situ* respiration tests approximately six months and one year after the initial pilot tests.

5.2 Regulatory Approval and Permits

Shaw AFB personnel are responsible for obtaining regulatory approval and all permits from the South Carolina Department of Health and Environmental Control (SCDHEC) that are required to perform the tests as described in this work plan. If required, Engineering-Science will assist this effort by providing test design criteria and reference documents for regulatory review. Unless directed by AFCEE or the Shaw AFB point of contact, no direct contact will be made between Engineering-Science and the regulatory agencies.

Based on previous bioventing experience at another Air Force base in South Carolina, the SCDHEC will require an Underground Injection Control (UIC) Permit for each site to perform any air injection into the subsurface. The UIC permit will regulate the vent wells as a Class V.A.-G injection wells (experimental technology). The permit will be required for both the short-term air permeability/respiration tests and the extended bioventing test. Therefore, the proposed testing schedule provided in Section 6 is dependent on timely permit approval by SCDHEC. The Agency will also issue approval for construction of the MPs and the vent wells. ES recommends that the base initiate the permitting process immediately upon receipt of this work plan.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	**Date**
Draft Test Work Plan to AFCEE/Shaw AFB	May 11, 1994
Approval to Proceed	May 27, 1994
Mobilization and System Installations	June 6, 1994
Begin Initial Field Tests	June 13, 1994
Complete Initial Field Tests and Begin Extended Tests	June 24, 1994
Interim Results Report	August 9, 1994
Six-Month Respiration Tests	December 1994
Final Respiration Test	June 1995

After a period of one year, a decision will be made by AFCEE and the base to either remove the system or to expand the system for full-scale remediation at the site.

7.0 POINTS OF CONTACT

Mr. Rick Roller/Mr. Randy Adams
20th Civil Engineering Squadron
20th CES/CEV
345 Cullen Street, Building 218
Shaw AFB, South Carolina 29152-5126
(803) 668-5207 or 668-4383

Lt. Col. Ross Miller/Mr. Jim Gonzales
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8.0 REFERENCES

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Shaw AFB, 1994. Personal communication, Ms. Lenna Eddings (20th CES/CEV) and Mr. Ray Alford (liquid fuels maintenance supervisor).

PART II

DRAFT
INTERIM BIOVENTING PILOT TESTS RESULTS REPORT
IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND
IRP SITE SS-15 (POL FUEL DEPOT)
SHAW AFB, SOUTH CAROLINA

Prepared for:

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BROOKS AFB, TEXAS

and

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PART II

DRAFT

INTERIM BIOVENTING PILOT TESTS RESULTS REPORT IRP SITE FT-01 (FORMER FIRE TRAINING AREA 1) AND IRP SITE SS-15 (POL FUEL DEPOT) SHAW AFB, SOUTH CAROLINA

Initial bioventing pilot testing and blower system installations were conducted at IRP Site FT-01 and IRP Site SS-15, located at Shaw Air Force Base (AFB), South Carolina from October 3 through November 19, 1994. Site FT-01 is an abandoned fire training area (Fire Training Area #1) and comprises base Operable Unit #4 (OU-4). The bioventing pilot testing and system installation was located within the bermed area of the former primary burn pit at Site FT-01, as depicted in Figure 1.1.

Site SS-15 is part of Operable Unit #1 (OU-1) and is located within the confines of the base POL bulk fuel storage facility (POL Depot). At Site SS-15, the bioventing pilot test was conducted adjacent to a former 1,000-gallon reclaimable fuel underground storage tank (UST) and above-ground fuel filter system. The bioventing pilot test location at Site SS-15 is shown in Figure 1.2.

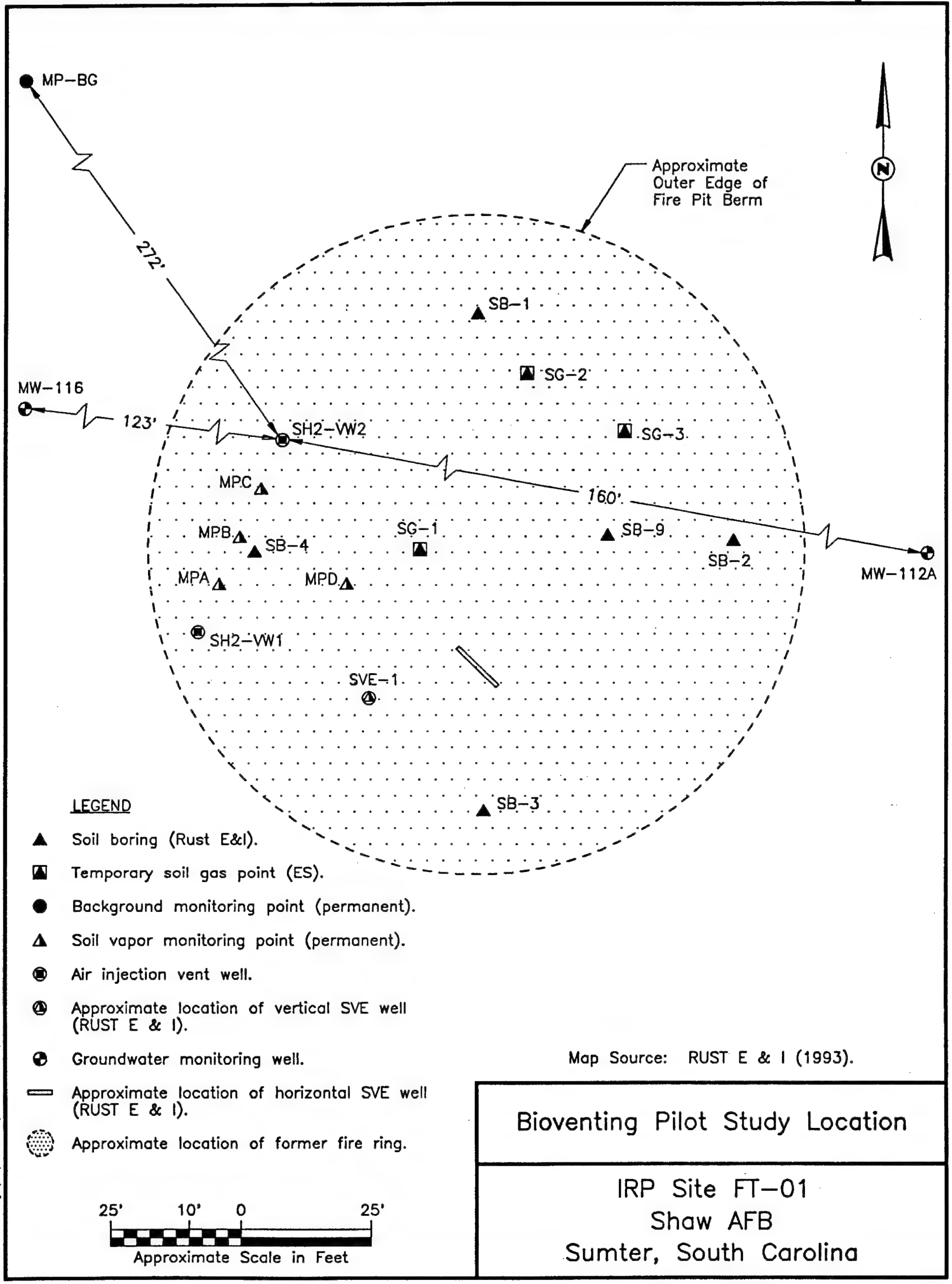
The purpose of this Part II report is to describe the results of the initial bioventing pilot tests at Sites FT-01 and SS-15 and to make specific recommendations for extended testing to determine the long-term impact of bioventing to remediate contaminants at each site. Descriptions of the history, geology, and contaminants of both sites are outlined in Part I of this report, *Bioventing Pilot Test Work Plan.*

1.0 PILOT TEST DESIGN AND CONSTRUCTION

Air injection vent wells (VWs), vapor/pressure monitoring points (VMPs), and underground injection piping systems were installed at both test sites from July 26-30, 1994. Initial field biorespiration tests, air permeability tests and blower shed installations were conducted at both sites from October 3-7, 1994 following regulatory inspections and permit approvals to operate the VWs. Final system piping, blower and electrical installations, and system startup were conducted from November 14-19, 1994.

Field installations and testing were supervised by the Cary, North Carolina office of Parsons Engineering Science, Inc. (Parsons ES; formerly Engineering-Science, Inc.). Figures 1.3 and 1.4 show the final locations of the bioventing system installations at Site FT-01 and Site SS-15, respectively. Subcontractor support was provided by Alliance Environmental, Inc. of New Ellenton, South Carolina for drilling and trenching/pipe installation services. Electrical subcontractor services were provided by WEB Electric, Inc. of Sumter, South Carolina for electrical installations and blower wiring. Installation and testing of both systems was directed by Mr. Grant Watkins, P.G., the Parsons ES site manager. The following sections of this report describe in more detail the final design, installation, and testing of the bioventing systems at both sites.

Figure 1.1



Bioventing Pilot Study Location

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

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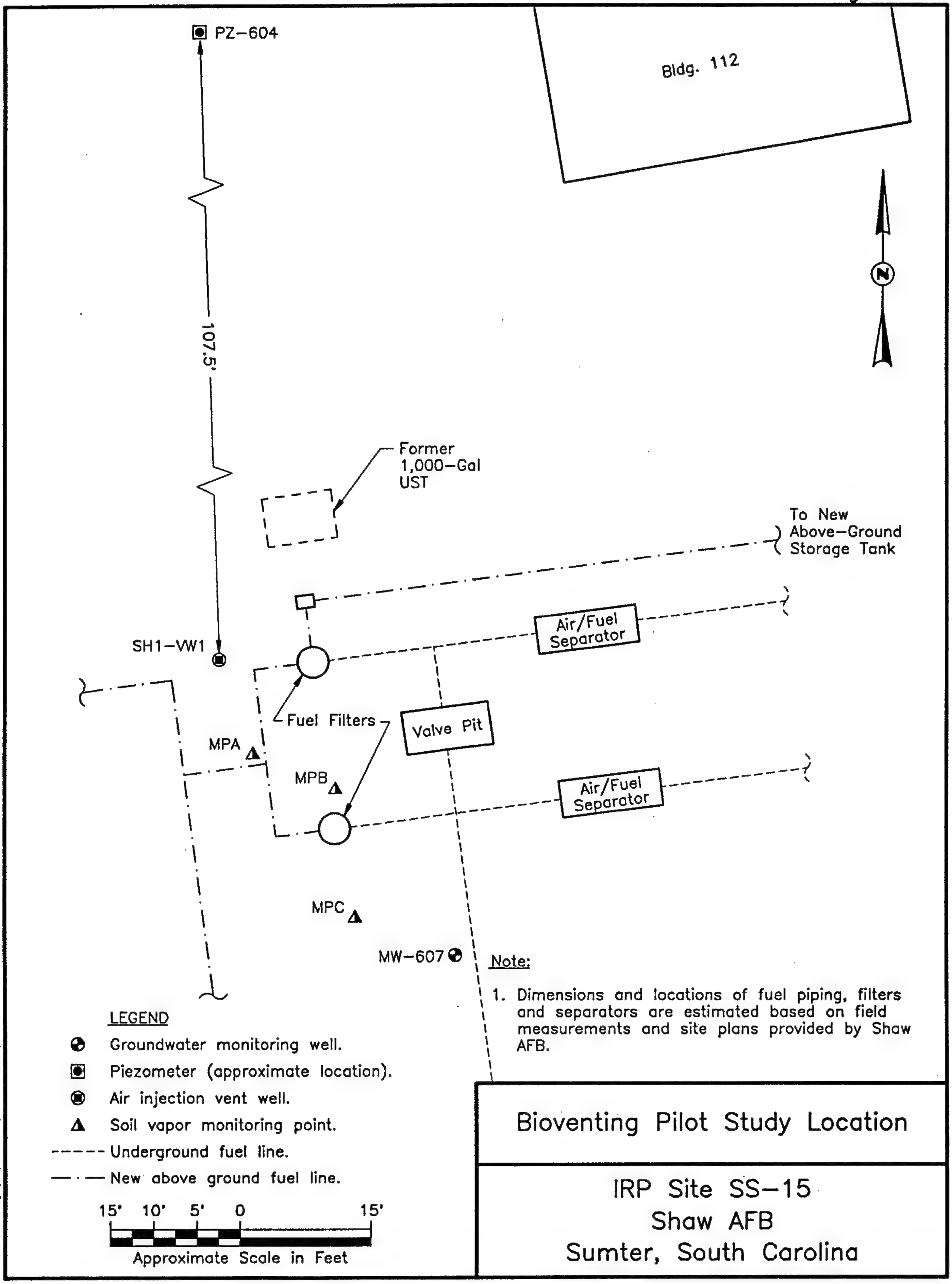
Figure 1.2



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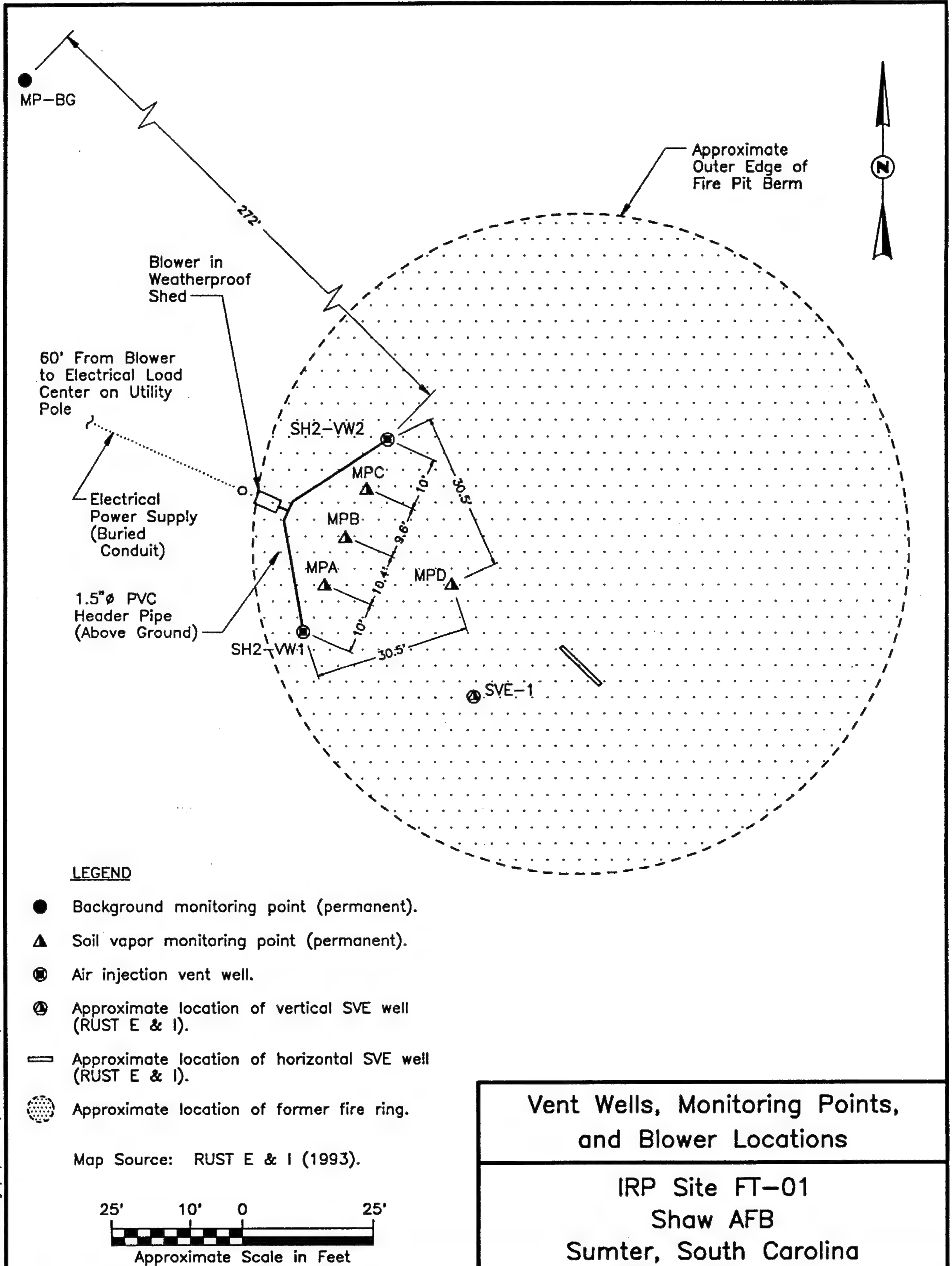
PARSONS ENGINEERING SCIENCE, INC.

Figure 1.3



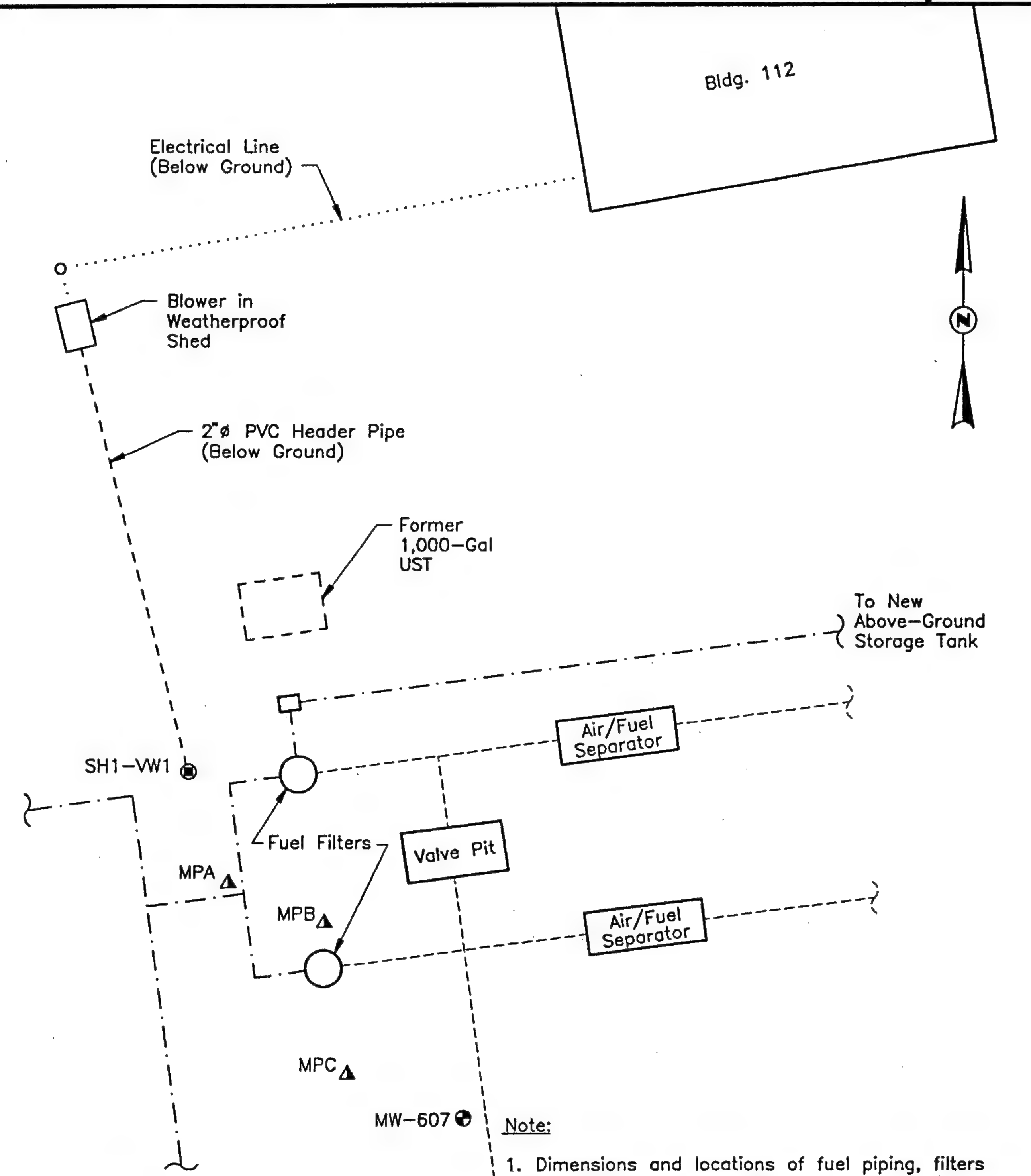
Vent Wells, Monitoring Points, and Blower Locations

IRP Site FT—01
Shaw AFB
Sumter, South Carolina

72240730.dwg / ps:1=1 / 12-14-94 / TLP

PARSONS ENGINEERING SCIENCE, INC.

Figure 1.4



Note:

1. Dimensions and locations of fuel piping, filters and separators are estimated based on field measurements and site plans provided by Shaw AFB.

LEGEND

- Groundwater monitoring well.
- Piezometer (approximate location).
- Air injection vent well.
- Soil vapor monitoring point.
- ----- Underground fuel line.
- —·— New above ground fuel line.

15' 10' 5' 0 15'

Approximate Scale in Feet

Vent Well, Monitoring Point, and Blower Locations

IRP Site SS–15
Shaw AFB
Sumter, South Carolina

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PARSONS ENGINEERING SCIENCE, INC.

Based on site conditions encountered by Parsons ES, minor changes to the Draft Work Plan were required for the bioventing systems' construction and layout. Considerations for altering the final bioventing designs are discussed below.

Site FT-01

Bioventing pilot testing and system installations at Site FT-01 generally complied with the Draft Work Plan. Although the final VMP and VW installations were moved slightly from the locations proposed in the Draft Work Plan, they remained inside the berm of the former burn pit. Based on air permeability test results, a rotary-vane compressor blower was installed for long-term air injection due to the low permeability of deeper soils at this site.

Site SS-15

At Site SS-15, the final locations and orientation of the VWs and VMPs were modified from the Draft Work Plan as a result of ongoing work by base contractors and unexpected site restrictions. As discussed in the Work Plan (Part I of this report), a Navy demolition/reconstruction project is ongoing at the Shaw AFB POL Depot to convert the former system of underground storage of JP-4 jet fuel to above-grade storage and transfer of JP-8 jet fuel. The Navy reversed their original plan to abandon *in-situ* the twenty-four USTs, and all the USTs and piping were excavated and removed from the site during July and August, 1994. The Navy's original design for the new above-grade fuel piping system was also modified. Soil grading operations and new piping installations were ongoing at the site during the bioventing VW and VMP installations, which further restricted access to areas originally targeted for the bioventing study.

Following submittal of the Draft Work Plan (May, 1994), Parsons ES was informed by Shaw AFB that a full-scale soil vapor extraction (SVE) remediation system would be designed and installed at the POL Depot by another base contractor. The SVE design will include the former UST basin immediately west of the bioventing test area. As a result of these site restrictions, the VMPs were moved slightly and reoriented from the locations proposed in the Draft Work Plan. Additionally, when drilling the VW borehole a concrete slab was encountered at a depth of 7 feet within the former 1,000-gallon reclaimable fuel UST pit. This required that the VW and VMPs be moved outside of the former UST excavation area.

1.1 Soil Gas Surveys of Pilot Test Areas

Parsons ES previously conducted limited soil vapor surveys of both pilot test sites during a base-wide search of candidate bioventing sites in March, 1994. During the soil gas surveys, temporary soil gas monitoring points were installed using a soil gas probe equipped with a retractable tip. Soil gas composition was screened for oxygen (O_2), carbon dioxide (CO_2), and total volatile hydrocarbons (TVH) concentrations. Additionally, existing monitoring wells and piezometers at the sites were sealed air-tight and their headspace soil gas was screened in a similar manner. The soil gas results, combined with field screening and visual observations (i.e. fuel staining) of soil samples collected during borehole drilling, were used to determine the final locations and screened intervals of the VMPs and VWs at each test site. Soil gas screening results are summarized in Sections 2.1.3 and 2.2.3, Part I (Work Plan) of this report.

1.2 Vent Well Installations

Air injection vent wells (VWs) were installed at both test sites according to the construction schematics proposed in the work plan. Drilling procedures and construction details for the VWs at each test site are discussed in the following sections.

1.2.1 Site FT-01 Vent Well Installations

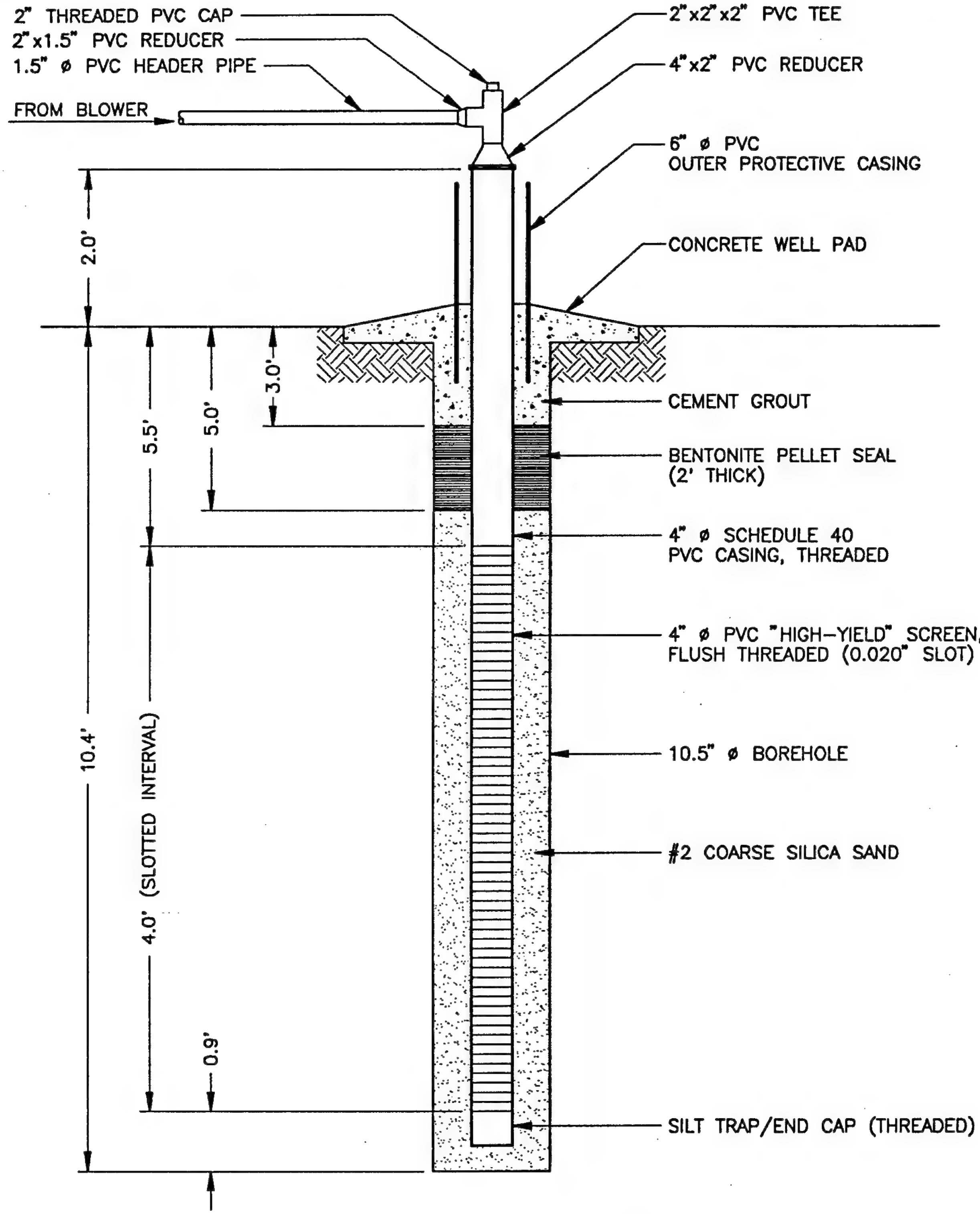
Two air injection VWs (SH2-VW1, SH2-VW2) were installed at Site FT-01 for interim testing and long-term use during the bioventing study. The VWs were located within the area of oxygen-depleted, fuel-contaminated soils identified during previous soil gas surveys and soil sampling events. The VWs were installed within the bermed perimeter of the former burn pit (see Figure 1.1). The VWs were also placed at a sufficient distance from the existing horizontal and vertical SVE wells installed by RUST E&I to prevent potential air short-circuiting with these structures. Figure 1.3 shows the VWs and VMP detailed layout for the bioventing system.

The VWs were installed using a mobile drill rig advancing 10.5-inch diameter hollow stem augers. Soil samples were collected at approximate 2-foot intervals using a 3-inch diameter split spoon sampling barrel. Each borehole was advanced to approximately 10.5 feet below ground surface (bgs). Soil lithologies were characterized by the field geologist and soil samples from each borehole were screened for organic vapors using a portable total volatile hydrocarbon (TVH) analyzer. Using the vapor screening results to establish relative contamination, one soil sample from vent well SH2-VW2 (7-foot depth) was submitted for laboratory analyses. Appendix A contains borehole logs and well construction records for the VWs and VMPs.

Both VWs were constructed using 4-inch diameter PVC screens and casing installed in the boreholes. The water table was not encountered during the VW installations. The perched groundwater zones observed on other parts of the site were not encountered during VW installations, although isolated zones of wet soil were observed during two of the VMP installations. Parsons ES installed the VWs to a total depth of 10.4 feet bgs. The screens and bentonite seals were installed below the suspected perched water table zone to ensure that an adequate length of screen would be exposed in the unsaturated zone and to prevent seepage of perched groundwater downward into the VW screens.

Figure 1.5 shows a typical construction schematic for the VWs at Site FT-01. One threaded, 5.0-foot screened section (4-foot actual slotted interval) was used to construct each VW. Both screen sections consist of 0.020-inch slotted "high-yield" screens surrounded by a coarse silica sand gravel pack. The "high-yield" screens have a greater number of slots per linear foot than do conventional monitoring well screens. The increased open area per linear foot of screen reduces pressure losses associated with the screen and improves air exchange between the VW and the formation. Each VW was completed with 2.0 feet of PVC casing stickup above ground surface. The well casing was surrounded by an outer protective PVC casing set in a concrete pad. A removable, threaded cap was installed on top of each wellhead so that a water level probe can be inserted into the VW if necessary.

Figure 1.5



NOTES:

1. Drawing is not to scale.
2. Vent wells were installed on 7-28-94.
3. Well construction schematic is typical for both vent wells SH2-VW1 and SH2-VW2.

As-Built Air Injection Vent Well Construction

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

72240713.dwg / 1=1 / 12-14-94 / TLP

PARSONS ENGINEERING SCIENCE, INC.

1.2.2 Site SS-15 Vent Well Installation

One air injection VW (SH1-VW1) was installed at Site SS-15 for interim testing and long-term use during the bioventing study. The VW was located within the general vicinity of oxygen-depleted, fuel-contaminated soils identified during previous soil gas surveys and soil sampling events. Parsons ES originally planned to install the VW within the former 1,000-gallon UST excavation area where fuel-saturated soils were observed during the tank removal. Three pilot boreholes drilled within the former excavation encountered a concrete slab at a depth of 7 feet bgs and, as a result, the VW was moved approximately 10 feet outside of the former UST excavation boundary (see Figure 1.4).

The VW was installed using a mobile drill rig advancing 10.5-inch diameter hollow stem augers. Soil samples were collected at 2-foot intervals using a 3-inch diameter split spoon sampling device. Split spoon samples were collected continuously at various borehole intervals based on lithology changes and apparent contamination. The VW borehole was advanced to 42 feet bgs. Soil lithologies were characterized by the field geologist and soil samples from the borehole were screened for organic vapors using both a photoionization detector (PID) and a portable TVH analyzer. Using the vapor screening results to establish relative contamination, one soil sample from the 40-foot depth was submitted for laboratory analyses. Appendix A contains borehole logs and well construction records for the VW and VMPs.

Figure 1.6 shows a construction schematic for vent well SH1-VW1. The VW was constructed with 29 feet (slotted interval) of 0.020-inch slotted "high-yield" screen, with a total VW depth of 41.75 feet bgs. A coarse silica sand pack was installed in the screened portion of the borehole annulus. The VW was completed subgrade in a 2'x2' flush-mount, locking well vault set in a concrete pad. A subsurface header pipe was constructed into the vault to connect the blower to the VW.

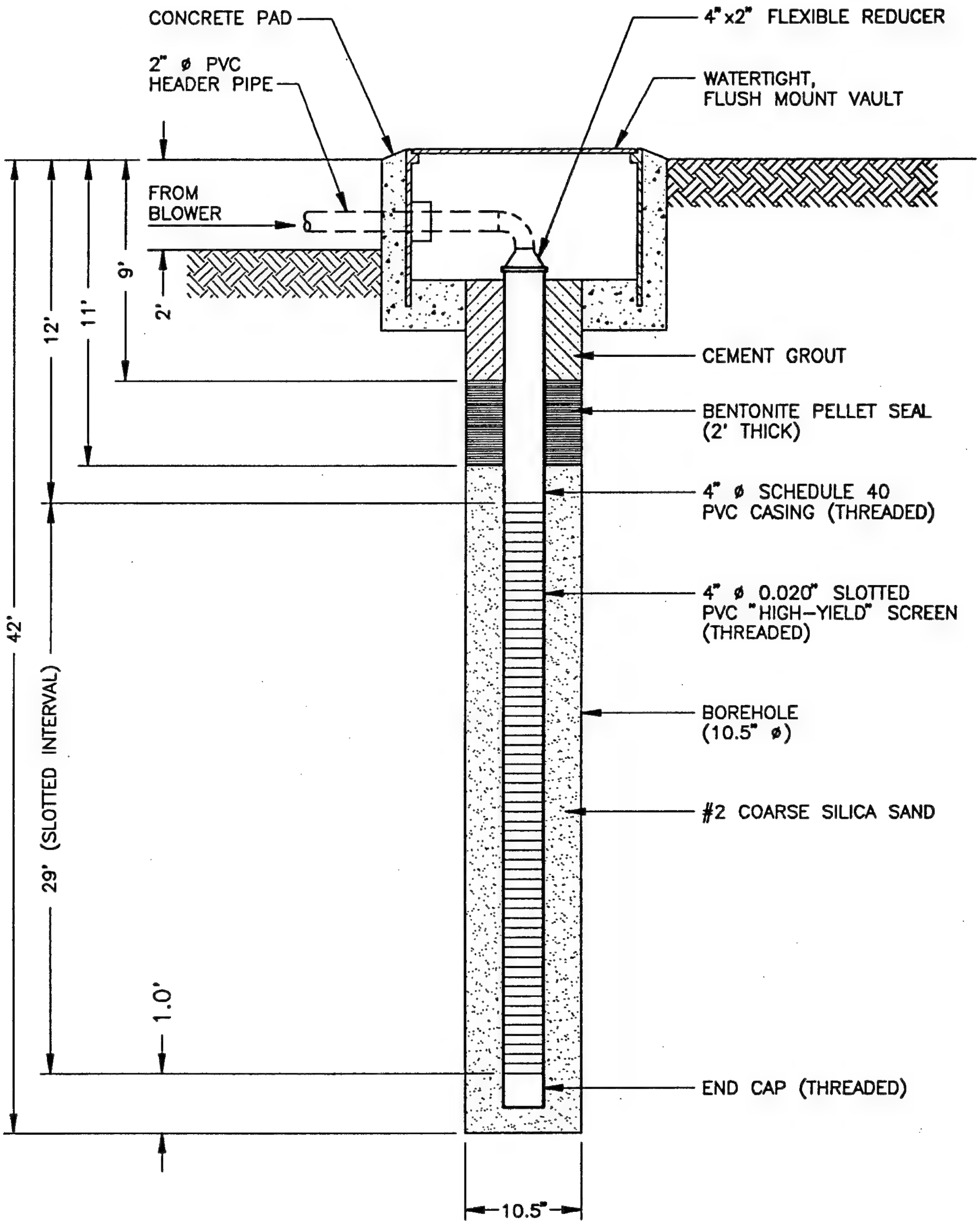
1.3 Vapor Monitoring Point Installations

A series of multi-depth VMPs were installed at each test site at various distances from the VWs. The VMPs were installed generally according to the specifications proposed in the work plan, although minor changes were made based on observed field conditions (reference Section 1.0). At Site SS-15, the final locations and orientation of the VMPs were changed due to the ongoing construction work and other site restrictions. Construction details for the VMPs at each test site are summarized in the following sections.

1.3.1 Site FT-01 VMP Installations

Four multi-depth VMPs were installed in the pilot test area according to the Draft Work Plan and bioventing test protocols. Three of the VMPs (SH2-MPA, SH2-MPB, SH2-MPC) were installed on approximate 10-foot centers on an axis between the two VWs (see Figure 1.3). The fourth VMP (SH2-MPD) was installed 30.5 feet from both VWs toward the east. Boreholes for the VMPs were advanced using a 4-inch (O.D.) stainless steel auger. Soil samples were collected from the boreholes at 1-foot and 2-foot intervals. The samples were described, inspected visually for fuel

Figure 1.6



NOTES:

1. Drawing is not to scale.
2. Vent well was installed on 7-26-94.

As-Built Air Injection Vent Well Construction

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

72240714.dwg / 1=1 / 12-14-94 / TLP

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contamination, and screened in the field for TVH headspace concentrations. Samples from two of the VMPs (SH2-MPA, SH2-MPC) were submitted for laboratory analyses (see Section 2.1).

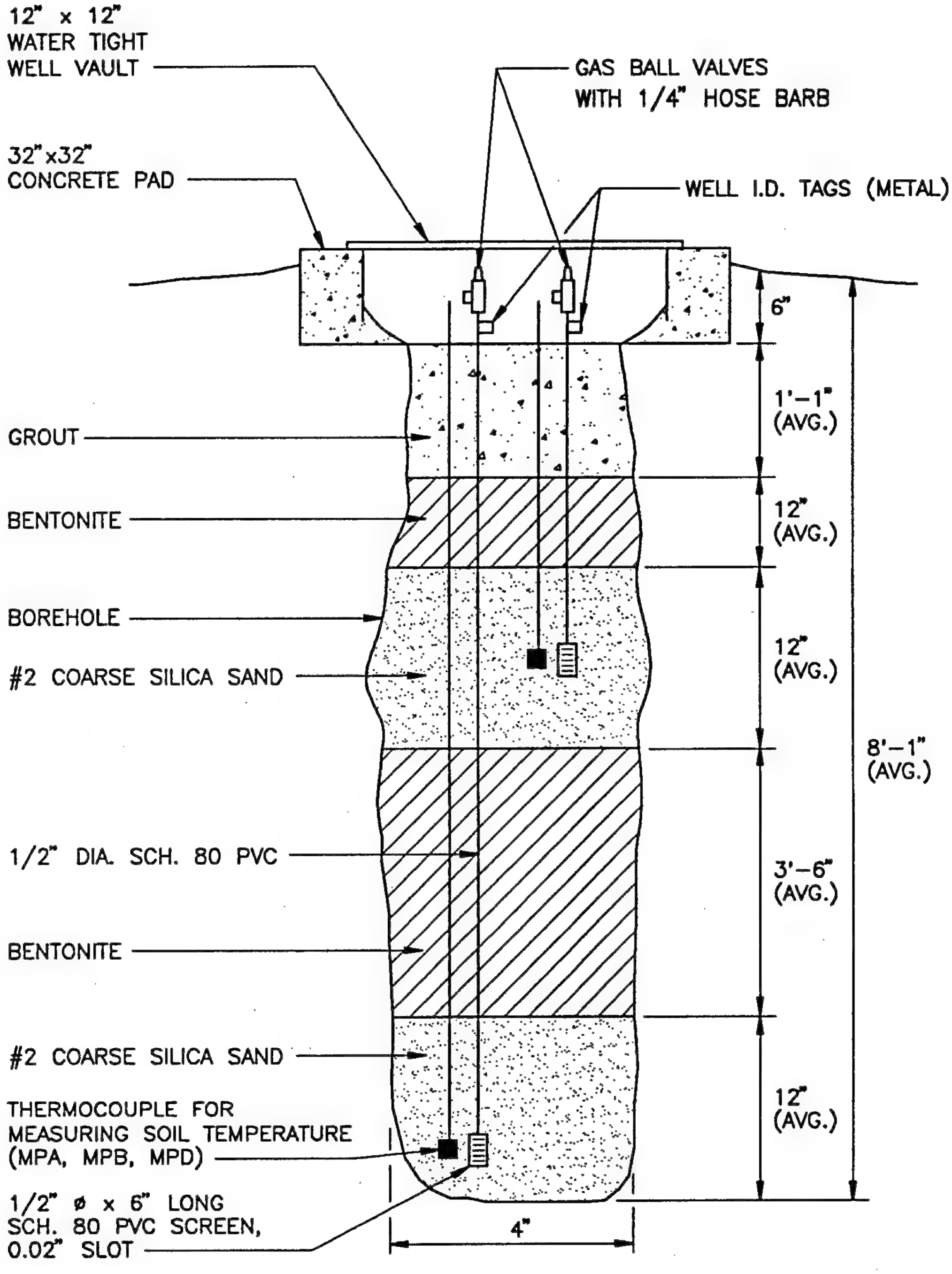
Each of the VMPs was constructed using 0.5-inch, schedule 80 PVC threaded screen (6-inch length) and casing. The top of each VMP was fitted air tight with a gas ball valve equipped with a hose barb. Three VMPs (SH2-MPA, SH2-MPB, SH2-MPD) were equipped with thermocouple probes to measure soil temperature. All four VMPs were similarly constructed as multi-depth monitoring points. The shallow VMP screened intervals were placed at depths ranging from 2.5-3 feet bgs to 4-4.5 feet bgs. The deeper screened intervals were placed from 7.5-8.0 feet bgs in all VMP boreholes. These screened intervals were selected to monitor soil gas conditions both above and below the suspected perched water table zone previously identified at this site. Figure 1.7 shows the typical as-built construction schematic for the VMPs at Site FT-01. Borehole logs and VMP construction records are included in Appendix A.

A background VMP, designated as SH2-BG1, was installed in clean soils 272 feet northwest of the VWs. The background VMP was constructed with 0.5-inch PVC with a screened interval of 7.5-8 feet bgs. The background VMP was used to monitor background soil gas conditions not affected by hydrocarbon contamination. Soil gas O_2 concentration at SH2-BG1 was 18.8 percent, indicating that abiotic and/or nonfuel O_2 uptake is not a major factor at this site. The background soil O_2 concentration observed at Site FT-01 was used as a representative background O_2 concentration for soils on this part of Shaw AFB.

1.3.2 Site SS-15 VMP Installations

Three multi-depth VMPs (SH1-MPA, SH1-MPB, SH1-MPC) were installed at Site SS-15. The VMPs were installed at distances of 11.5 feet, 20.0 feet, and 34.6 feet in a general south-southeast direction from the VW (see Figure 1.4). Boreholes for the VMPs were advanced using an 8.25-inch (O.D.) hollow stem auger. Soil samples were collected from the boreholes at 2-foot intervals using a split spoon sampler and were screened in the field for organic vapor concentrations. Samples from two of the VMPs (SH1-MPA, SH1-MPB) were submitted for laboratory analyses (see Section 2.1).

Each of the multi-depth VMPs was constructed using 0.75-inch threaded PVC screen (9-inch length) and casing. The top of each VMP was fitted air tight with a gas ball valve equipped with a hose barb. Two VMPs (SH1-MPA and SH1-MPB) were equipped with thermocouple probes to measure soil temperature. All three VMPs were similarly constructed as multi-depth monitoring points. Monitoring points SH1-MPA and SH1-MPB were constructed with three, 9-inch screened intervals having total depths of 10 and 12, 24, and 38 feet bgs. Monitoring point SH1-MPC was constructed with only two screened intervals placed from 19.25 to 20 feet bgs and from 37.25 to 38 feet bgs. These screened intervals are expected to remain above the water table throughout the year. Figure 1.8 shows the typical construction schematic for the VMPs at Site SS-15. Borehole logs and VMP construction records are included in Appendix A.



MONITORING POINT CONSTRUCTION DETAILS

Monitoring Point No.	Screened Intervals (FT)	Thermocouple Depths (FT)
SH2-MPA	4-4.5/7.5-8	8
SH2-MPB	3.5-4/7.5-8	4/8
SH2-MPC	2.5-3/7.5-8	NA
SH2-MPD	2.5-3/7.5-8	3
SH2-BG1	7.5-8	NA

DRAWING IS NOT TO SCALE

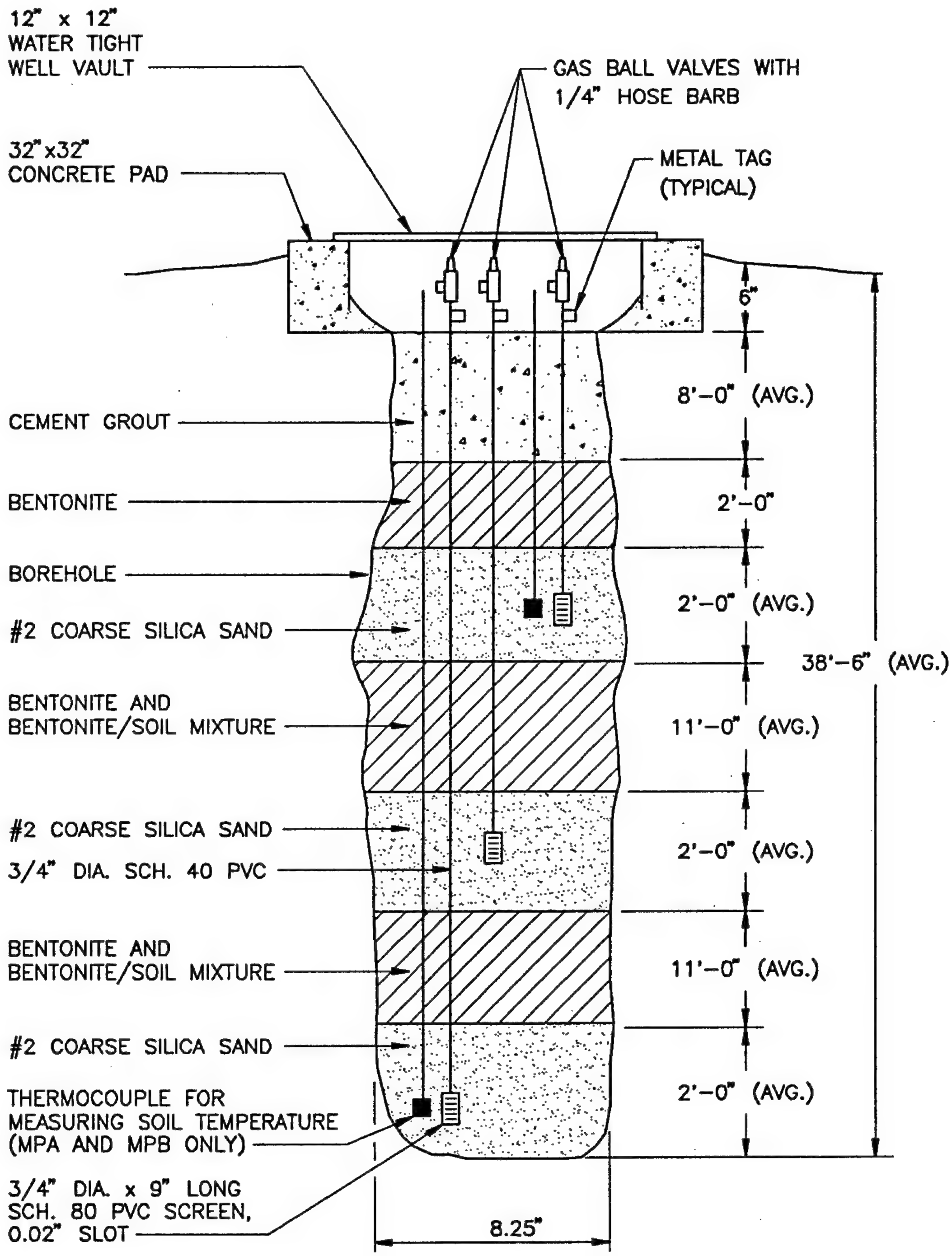
As-Built Monitoring Point Construction Detail

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

72240715.dwg / 1=1 / 12-14-94 / TLP

PARSONS ENGINEERING SCIENCE, INC.

Figure 1.8



MONITORING POINT CONSTRUCTION DETAILS

Monitoring Point No.	Screened Intervals (FT)	Thermocouple Depths (FT)
SH1-MPA	11.25-12	12
	23.25-24	24
	37.25-38	38
SH1-MPB	9.25-10	10
	23.25-24	NA
	37.25-38	38
SH1-MPC	19.25-20	NA
	37.25-38	NA

DRAWING IS NOT TO SCALE

As-Built Monitoring Point Construction Detail

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

72240716.dwg / 1=1 / 12-14-94 / TLP

PARSONS ENGINEERING SCIENCE, INC.

A background VMP was not installed within the POL Depot. An upgradient "clean" groundwater monitoring well (MW-637) within the POL Depot was fitted air-tight and screened for soil gas composition to determine if abiotic and/or nonfuel O_2 uptake is a factor at this site. The background well indicated that soils in the upgradient areas of the POL Depot are affected by elevated concentrations of organic vapor contamination. Soil gas headspace O_2 concentration at the well was 0.0 percent and TVH concentration was >10,000 parts per million by volume (ppmv). Parsons ES also noted that organic vapors in the background well had a nonfuel, solvent-like odor, which may be indicative of a groundwater plume of chlorinated solvents known to exist on this part of the base. Since soil vapor contamination is apparently widespread in the vicinity of the POL Depot, an upgradient well (MW-19A) on another part of the base was sampled for representative background soil O_2 (reference Section 3.4.2).

1.4 Blower System Installations

1.4.1 Site FT-01 Blower System

A 1.5-horsepower Gast model 2567-P102 rotary vane blower and air injection piping system were installed at Site FT-01 for extended pilot testing. A rotary vane blower was installed due to the low air permeability results obtained at this site (see Section 3.2.1). The Gast blower was installed in a locking, weatherproof enclosure. Air is delivered to the VWs through an above-ground, PVC manifold (header) piping system. Each segment of the manifold pipe is equipped with a PVC ball valve so that the air flow to each VW can be controlled individually. This configuration will allow one VW to be shut down, while the other VW receives air injection. Figure 1.9 shows the process instrumentation and specifications for the blower and air injection system.

During the initial air permeability and respiration field testing, electrical power was not available at Site FT-01 and the permanent blower was not installed. Parsons ES used a Gast model 2067 rotary vane compressor pump operated by a gas-powered generator to perform the initial air permeability test at this site. Electrical power was installed at the site in November 1994 and the permanent blower was wired and commenced operation for the extended pilot test on November 18, 1994.

1.4.2 Site SS-15 Blower System

A 1-horsepower Gast R4110-2 regenerative blower and air injection piping system were installed at Site SS-15 for extended pilot testing. The Gast blower was installed in a locking, weatherproof enclosure. Air is routed to the VW through a subsurface, PVC header pipe (see Figure 1.4). The as-built process instrumentation and specifications for the blower and air injection system are illustrated in Figure 1.10.

During the initial air permeability and respiration field testing, electrical power was not available at Site SS-15 and the permanent blower was not installed at that time. Parsons ES used a portable Rotron model DR-505 centrifugal blower to perform the initial air permeability test at the site. Electrical power was installed at the site in November 1994 and the regenerative blower was wired and began operation for the extended pilot test on November 18, 1994.

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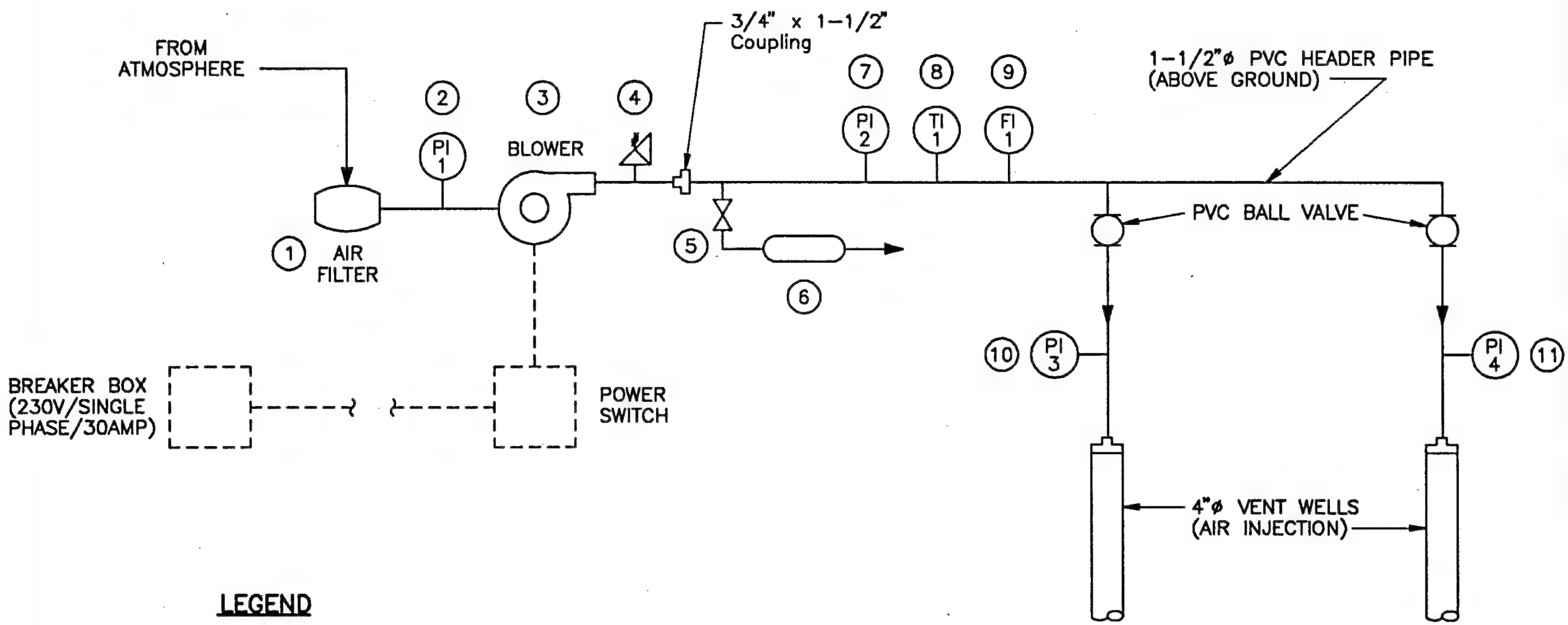

LEGEND

1. INLET AIR FILTER: SOLBERG F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. BLOWER: GAST 2567-P102 (ROTARY VANE)
4. AUTOMATIC PRESSURE RELIEF VALVE
5. MANUAL PRESSURE RELIEF (AIR BLEED) VALVE: 1-1/2" GATE VALVE
6. NOISE-DAMPENING MUFFLER
7. PRESSURE GAUGE (PSI)
8. TEMPERATURE GAUGE (°F)
9. AIR FLOW GAUGE (THERMAL ANEMOMETER PORT)
10. PRESSURE GAUGE (PSI)
11. PRESSURE GAUGE (PSI)

DRAWING IS NOT TO SCALE

As-Built Blower System for Air Injection

IRP Site FT-01
Shaw AFB
Sumter, South Carolina

Figure 1.9

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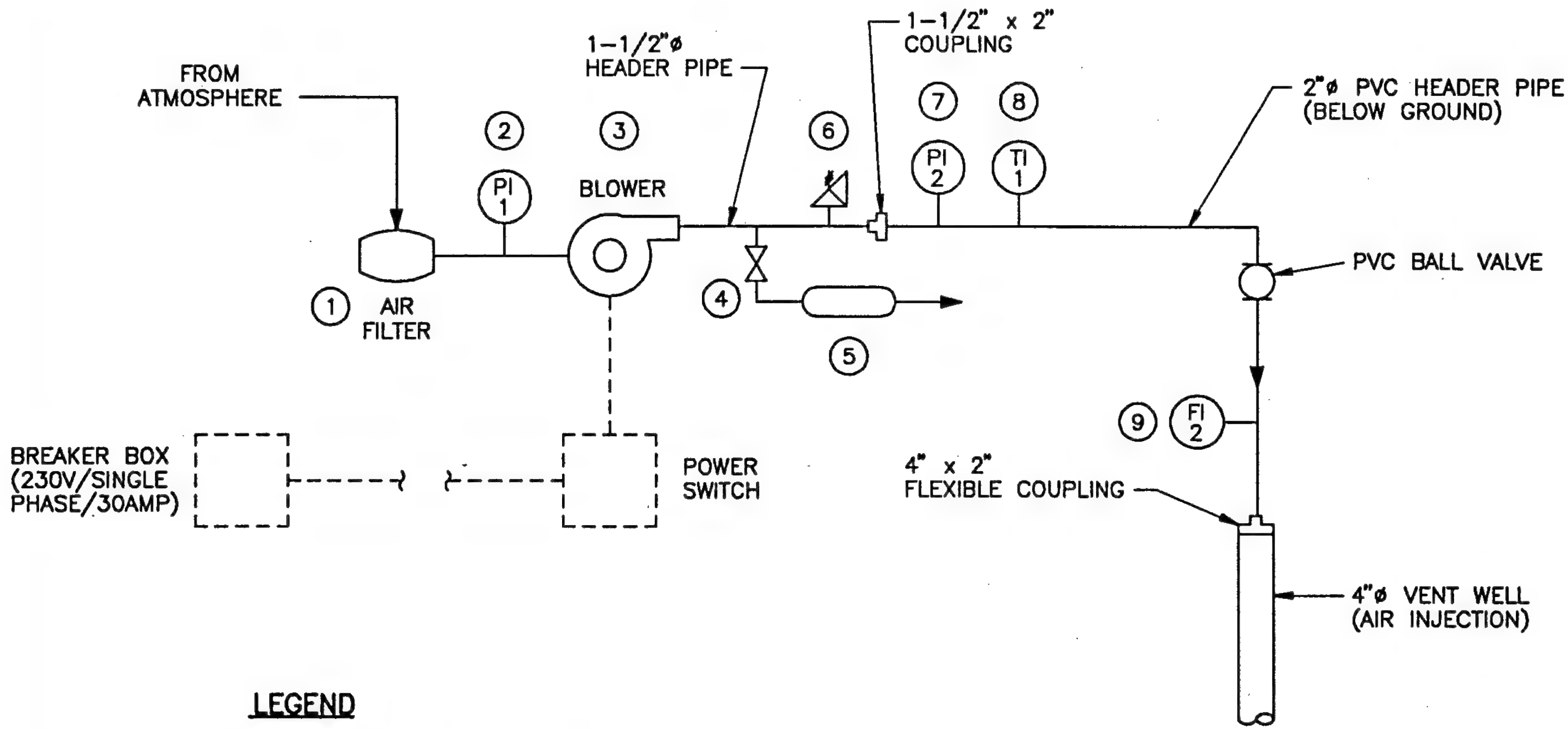


LEGEND

1. INLET AIR FILTER: SOLBERG F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. BLOWER: GAST R4110-2
4. MANUAL PRESSURE RELIEF (AIR BLEED) VALVE: 1-1/2" GATE VALVE
5. NOISE-DAMPENING MUFFLER
6. AUTOMATIC PRESSURE RELIEF VALVE
7. PRESSURE GAUGE (IN. H_2O)
8. TEMPERATURE GAUGE (°F)
9. AIR FLOW GAUGE (THERMAL ANEMOMETER PORT)

DRAWING IS NOT TO SCALE

As-Built Blower System for Air Injection

IRP Site SS-15
Shaw AFB
Sumter, South Carolina

Figure 1.10

2.0 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.1 Soil Sampling Results

During installation of the VW and VMP boreholes, soil samples were collected at regular intervals for field screening of hydrocarbon organic vapors. Soil headspace organic vapor screening was conducted at both sites using a portable TVH analyzer equipped with a methane elimination switch. Soil samples from two boreholes at the POL Depot were also screened with a photoionization detector (PID) to compare readings between the two field instruments (reference soil boring logs, Appendix A).

Three sets of soil samples were collected from each test site for laboratory analyses. Soil samples from both sites were analyzed by the PACE, Inc. laboratory in Huntington Beach, California for these parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene, xylenes (BTEX); iron; alkalinity; pH; total Kjeldahl nitrogen (TKN); phosphates; percent moisture; and particle size distribution. One soil sample was collected from SH2-BG1 at Site FT-01 for TKN analysis to establish a representative background concentration for this parameter.

2.1.1 Site FT-01 Soil Sampling Results

At Site FT-01 soil samples for laboratory analyses were collected from SH2-VW2 (7-foot depth), SH2-MPA (5.5-foot depth), and SH2-MPC (8-foot depth). Soil organic vapor concentrations generally increased with depth and fuel staining was visible in many of the samples. For comparative evaluation, soil samples for laboratory analyses were collected from approximately the same depths as the VMP screen intervals.

Table 2.1 summarizes results of the soil analyses at Site FT-01. TRPH concentrations ranged from 3,350 milligrams per kilogram (mg/kg) at SH2-VW2-7 to 6,310 mg/kg at SH2-MPC-8. Soil total BTEX concentrations ranged from 5.44 to 11.52 mg/kg. Benzene was detected in sample SH2-VW2-7 at 0.52 mg/kg, but it was not detected in the other two samples. TKN was less than the 100 mg/kg detection limit at background sampling point SH2-BG1-8. TKN was detected in the three other samples at concentrations ranging from 110 mg/kg (SH2-MPC-8) to 290 mg/kg (SH2-VW2-7). The lower concentration of background TKN appears to be anomalous for this site, but it may be the result of metabolic processes by nitrogen-fixing bacteria in the contaminated soils. Protein foams used to extinguish fires in the burn pit could also produce a higher soil nitrogen content in this area.

2.1.2 Site SS-15 Soil Sampling Results

At Site SS-15, soil samples were collected for laboratory analyses from SH1-VW1 (40-foot depth), SH1-MPA (38-foot depth), and SH1-MPB (38-foot depth). Soil headspace organic vapor concentrations varied both with depth and with distance from the former 1000-gallon UST excavation. For comparative evaluation, soil samples for laboratory analyses were collected from the same general depths as the VMP screen intervals.

Table 2.2 summarizes results of the soil analyses at Site SS-15. TRPH concentrations ranged from 923 milligrams per kilogram (mg/kg) at SH1-MPB-38 to 4,280 mg/kg at SH1-VW1-40. Soil total BTEX concentrations ranged from 10.4 mg/kg (SH1-MPB-38) to 92.7 mg/kg (SH1-VW1-40). The highest benzene

TABLE 2.1

SOIL AND SOIL GAS ANALYTICAL RESULTS
IRP SITE FT-01
SHAW AFB, SOUTH CAROLINA

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	VW2-7	MPA-5.5	MPC-8
TRPH (mg/kg)	3,350	3,750	6,310
Benzene (mg/kg)	0.52	<0.28	<0.55
Toluene (mg/kg)	2.2	0.94	1.9
Ethylbenzene (mg/kg)	4.9	1.9	3.9
Xylenes (mg/kg)	3.9	2.6	3.2
Soil Gas Hydrocarbons[b]	VW1	MPA-8	MPC-3
TVH (ppmv)	1,300	24,000	1,200
Benzene (ppmv)	1.5	59	1.0
Toluene (ppmv)	1.2	97	3.0
Ethylbenzene (ppmv)	1.6	36	3.4
Xylenes (ppmv)	7.3	69	6.8
Soil Inorganics	VW2-7	MPA-5.5	MPC-8
Iron (mg/kg)	5,850	5,170	1,410
Alkalinity (mg/kg as $CaCO_3$)	<44.6	<44.9	<43.9
pH (units)	5.6	5.5	5.6
TKN (mg/kg)	290	160	110
Phosphates (mg/kg)	47	36	30
Soil Physical Parameters	VW2-7	MPA-5.5	MPC-8
Moisture (% wt.)	10.5	11.1	9.0
Gravel (%)	0.4	0.0	0.2
Sand (%)	73.8	71.3	80.5
Silt (%)	7.3	5.9	7.1
Clay (%)	18.5	22.7	12.2

a/ TRPH = Total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram; TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ Laboratory analyses by EPA Method TO-3

TABLE 2.2

SOIL AND SOIL GAS ANALYTICAL RESULTS
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	VW1-40	MPA-38	MPB-38
TRPH (mg/kg)	4,280	1,880	923
Benzene (mg/kg)	3.6	1.3	<0.29
Toluene (mg/kg)	8.1	3.0	<0.29
Ethylbenzene (mg/kg)	13	6.6	1.8
Xylenes (mg/kg)	68	32	8.6
Soil Gas Hydrocarbons[b]	VW1	MPA-24	MPC-38
TVH (ppmv)	58,000	41,000	110,000
Benzene (ppmv)	160	63	410
Toluene (ppmv)	140	160	310
Ethylbenzene (ppmv)	20	32	45
Xylenes (ppmv)	77	100	180
Soil Inorganics	VW1-40	MPA-38	MPB-38
Iron (mg/kg)	7,280	21,200	13,300
Alkalinity (mg/kg as $CaCO_3$)	<41.7	<43.8	<46.8
pH (units)	5.2	5.2	5.3
TKN (mg/kg)	<40	<40	<40
Phosphates (mg/kg)	310	210	250
Soil Physical Parameters	VW1-40	MPA-38	MPB-38
Moisture (% wt.)	6.9	10.9	15.2
Gravel (%)	0.7	0.0	0.0
Sand (%)	85.3	79.5	79.6
Silt (%)	4.1	5.7	5.7
Clay (%)	10.0	14.7	14.7

a/ TRPH = Total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram; TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ Laboratory analyses by EPA Method TO-3.

concentration was 3.6 mg/kg at SH1-VW1-40. TKN was not detected in any of the soil samples above the laboratory-detection limit of 40 mg/kg for this parameter. A background TKN sample was not collected for this site.

2.2 Soil Gas Sampling Results

Soil gas samples were collected from three VMPs at each test site using SUMMA^R canisters. The samples were collected according to bioventing program protocols and were laboratory-analyzed for total volatile hydrocarbons (TVH) and BTEX compounds by EPA Method TO-3. The SUMMA^R canister samples were analyzed by the Air Toxics, Ltd. laboratory in Folsom, California.

2.2.1 Site FT-01 Soil Gas Results

At Site FT-01, soil gas SUMMA^R canister samples were collected from SH2-VW1, SH2-MPA-8, and SH2-MPC-3. Analytical results showed soil gas TVH concentrations ranging from 1,200 ppmv (SH2-MPC-3) to 24,000 ppmv (SH2-MPA-8). Individual BTEX compounds were detected in all three soil gas samples. Total BTEX concentrations ranged from 11.6 ppmv to 261 ppmv. The highest benzene concentration was 59 ppmv at SH2-MPA-8. Table 2.1 summarizes the soil gas laboratory analytical results for Site FT-01.

2.2.2 Site SS-15 Soil Gas Results

Soil gas SUMMA^R canister samples were collected from SH1-VW1, SH1-MPA-24, and SH1-MPC-38 at Site SS-15. Analytical results showed soil gas TVH concentrations ranging from 41,000 ppmv (SH1-MPA-24) to 110,000 ppmv (SH1-MPC-38). Individual BTEX compounds were detected in all three soil gas samples. Total soil gas BTEX concentrations ranged from 355 ppmv to 945 ppmv. The highest benzene concentration was 410 ppmv at SH1-MPC-38. Table 2.2 summarizes the soil gas laboratory analytical results for Site SS-15.

2.3 Lithologic and Hydrogeologic Characterization

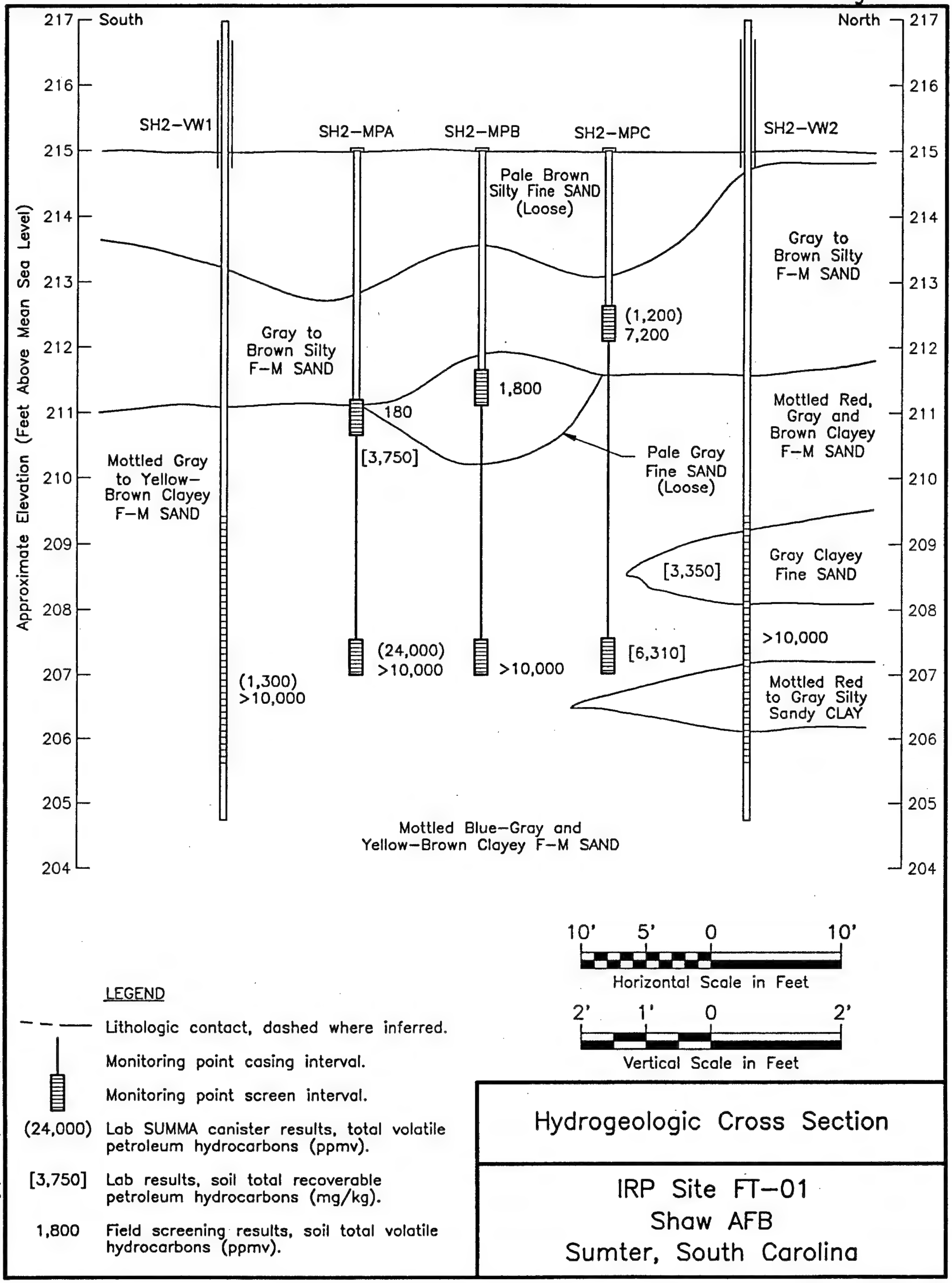
2.3.1 Site FT-01 Lithology and Hydrogeology

Figure 2.1 illustrates a hydrogeologic cross section for Site FT-01 based on lithologic descriptions made during the VMP and VW installations. Residual soils encountered at Site FT-01 consisted primarily of gray to pale brown, silty to clayey fine to medium sands in the upper 10 feet of the soil column. These sediments are part of the Upper Duplin Formation. The amount of silt, clay, and moisture content in the soil matrix varies both laterally and vertically, creating apparent differences in soil permeability over short distances.

The upper 3.5 to 5 feet of the soil profile consists of a highly permeable gray to brown silty fine to medium sand. This silty sand unit is rather consistent across the site and was encountered in all of the soil borings. The top 1 to 2 feet of this unit are very loose, slightly silty fine sand. Discontinuous lenses of loose, fine sand were encountered within this unit. Soils from several borings contained visible fuel staining and strong fuel odors within the upper silty sand unit.

Soil silt and clay content increases significantly beginning at a depth of about 4.5 to 5 feet. This clayey sand strata represents the lithologic interval that creates the perched groundwater zone identified in soil borings advanced during prior IRP investigations.

Figure 2.1



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Parsons ES did not observe a continuous perched water table at this depth during soil boring installations. The soils were moderately wet to saturated at 5-foot depths in borings SH2-MPD, SH2-VW1, and SH2-VW2, suggesting that perched groundwater is probably a localized phenomenon at this site.

Soil mottling is present within the clayey sand unit and the color varies from red to yellow-brown to pale blue-gray. The clay content and moisture content of the clayey sand unit appeared to decrease slightly with depth at most soil borings. Particle size analyses of samples collected from the clayey sand unit below the 5-foot depth show approximately 71.3% to 80.5% sand-size particles (see Table 2.1). The clay content decreased consistently with depth from 22.7% (SH2-MPA-5.5) to 18.5% (SH2-VW2-7) to 12.2% (SH2-MPC-8).

The permanent water table occurs within the lower clayey sand unit and it fluctuates on both a short-term and seasonal basis. Localized, discontinuous zones of perched groundwater occur at the site, probably as a temporary condition following rainfall events. Parsons ES measured water levels in adjacent shallow monitoring wells MW-116 and MW-112 twice and found that the water table averaged about 11.5 feet bgs in March 1994 to 12.5 feet bgs in July 1994. During these same gauging events, water levels at SVE-1 in the center of the burn pit ranged from about 4.3 feet bgs to 5.25 feet bgs, indicating a local influence from perched groundwater.

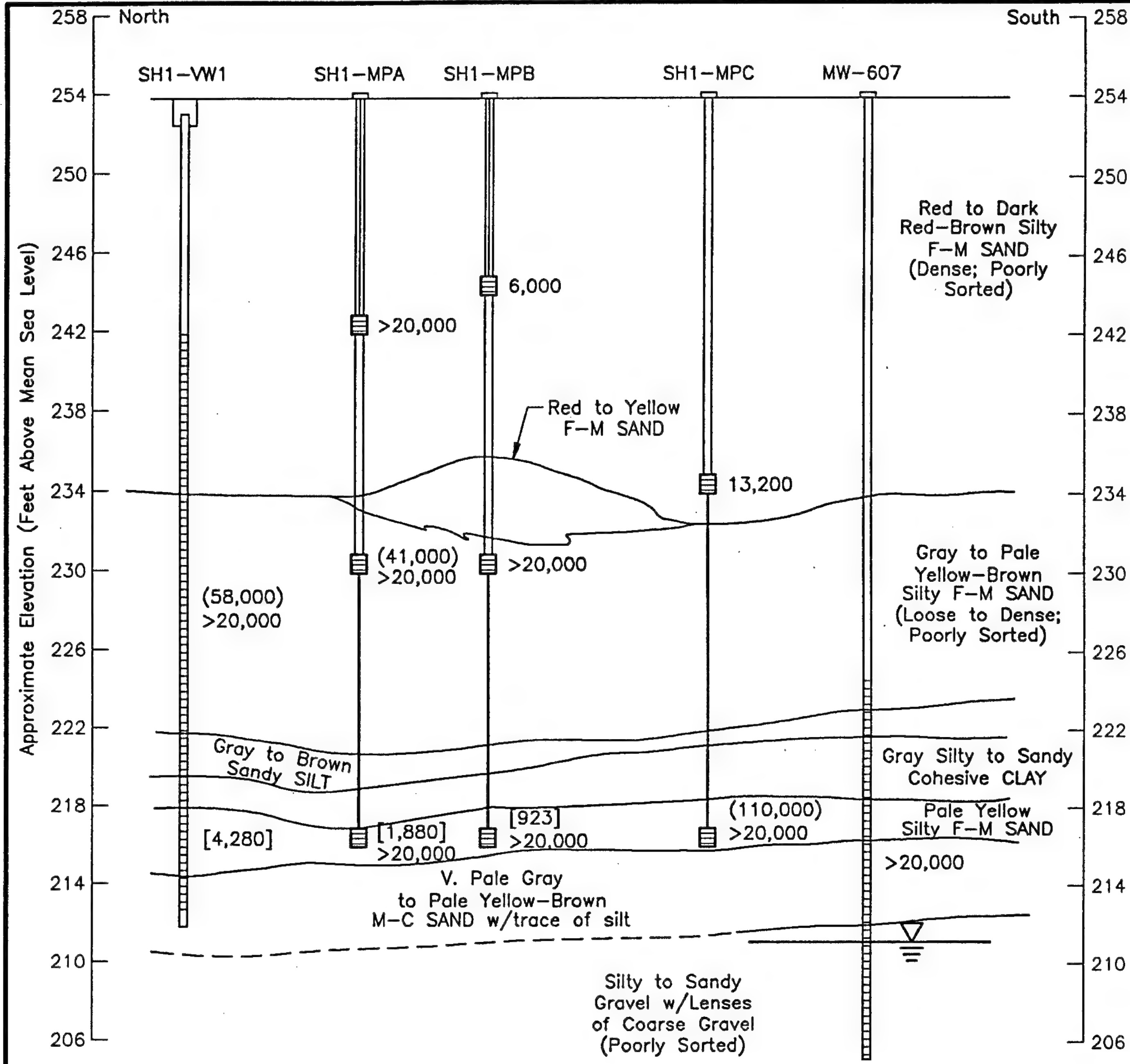
Vapor monitoring points SH2-MPD-8 and SH2-MPC-8 have contained water since their initial construction and could not be used during the initial field testing. Vapor monitoring point SH2-MPD is located near the center of the burn pit and is probably affected by perched groundwater and poor drainage conditions observed in this area. Soils from boring SH2-MPD encountered saturated conditions from 4 feet to 8 feet bgs. Soils collected from boring SH2-MPC were not saturated at any depth. The presence of water in the well screen of SH2-MPC-8 could be the result of well construction (i.e. bentonite hydration) or a localized water table anomaly.

Parsons ES noted that both VWs were dry (i.e. water table >9.5 feet bgs) at the time of their installation on July 28, 1994, again on September 21, 1994 and again on October 3, 1994 prior to field respiration testing. Conversely, well SH2-VW2 had water at 9.4 feet bgs, and well SH2-VW2 remained dry, on October 5, 1994 after 3 inches of precipitation two days earlier. On November 17, 1994 well SH2-VW1 had a water level of 8.96 feet bgs and all of the deeper VMPs (8-foot depths) recovered groundwater during purging. These observations, made over an 8-month period, demonstrate that the hydraulic relationship between the saturated and unsaturated zones is complex and dynamic at this site.

2.3.2 Site SS-15 Lithology and Hydrogeology

Figure 2.2 illustrates a hydrogeologic cross section for the bioventing pilot study area of Site SS-15. The cross section is based on lithologic descriptions made during the VMP, VW and adjacent groundwater monitoring well installations. Three distinct and rather uniform lithologic strata were observed in the upper 50 feet of the soil profile. These unconsolidated sediments represent terrace deposits of the Upper Duplin Formation.

Figure 2.2



LEGEND

Water table surface.

Lithologic contact, dashed where inferred.

Monitoring point casing interval.

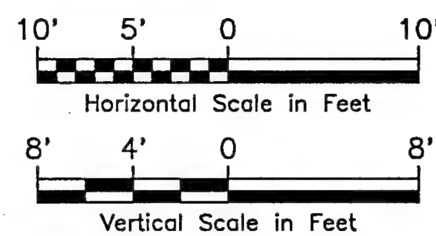
Monitoring point screen interval.

(58,000) Lab SUMMA canister results, total volatile petroleum hydrocarbons (ppmv).

[4,280] Lab results, soil total recoverable petroleum hydrocarbons (mg/kg).

13,200 Field screening results, soil total volatile hydrocarbons (ppmv).

Note: Water table depth shown at well MW–607 was measured on 7–26–94.



Hydrogeologic Cross Section

IRP Site SS–15
Shaw AFB
Sumter, South Carolina

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The three stratigraphic units encountered in the upper 50 feet of the bioventing study area are generally described as follows:

0'-32' bgs: Red to dark reddish-brown poorly-sorted silty fine to medium sand (0'-20') grading into a gray to pale brown moderately-sorted silty fine to medium sand (20'-32');

32'-36' bgs: Gray to brown sandy silt (32'-33') grading into a stiff, cohesive silty to sandy clay (33'-36');

36'-50'+ bgs: Pale Gray to yellow-brown silty fine to medium sand (36'-38') grading into a pale yellow-brown well-sorted medium to coarse sand with lenses of silty sand and coarse gravel (38'-50'+).

The first 18 to 20 feet of the upper silty sand unit is poorly sorted and moderately to densely compacted, resulting in overall low permeability. This silty sand unit changes color and is less dense from 20 feet to its contact with the silt/clay unit at approximately 32 feet bgs. The upper silty sand unit is relatively dry, with the exception of the top 6 feet which had a higher apparent moisture content.

The silt/clay unit is a low-permeability strata occurring from approximately 32 to 36 feet bgs. The thickness and depth of this unit varied slightly between each soil boring location. Soils in the sandy clay portion of this unit were wet and contained strong fuel odors. The low-permeability clay layer likely retards downward groundwater flow based on its observed water-saturated condition and physical characteristics.

Unconsolidated sediments of the lower sand unit begin as a poorly-sorted silty sand that grades downward into a coarse, well-sorted sand with high visual porosity and permeability. Soil grain size analyses from the upper portion of the lower sand unit (see Table 2.2) show a sand content ranging from 79.5% (SH1-MPA-38) to 85.3% (SH1-VW1-40). The clay content ranged from 14.7% (SH1-MPA-38 and SH1-MPB-38) to 10% (SH1-VW1-40). Soil boring logs from adjacent well MW-607 describe a silty gravel to coarse sandy gravel layer from 42 feet to 48 feet bgs.

Groundwater in this portion of the POL Depot is found in the lower coarse sand unit and reportedly occurs under unconfined, water table conditions. Parsons ES gauged water levels in several surrounding monitoring wells and measured groundwater at an average depth of about 43.5 feet bgs. The screened interval of the VW for this site did not penetrate the water table. There is neither a perched water table condition nor confined groundwater condition associated with the low-permeability silt/clay unit (32'-36' bgs) within the pilot study area. Although the clay layer is wet to saturated, soils immediately above and below the clay layer are unsaturated.

During a well gauging event (7/26/94), Parsons ES detected floating, non-aqueous phase liquid (NAPL) fuel (i.e "free-product" fuel) in nearby wells MW-607 and MW-608. The product thicknesses were 0.70 feet and 2.15 feet in wells MW-607 and MW-608, respectively. These results indicate that NAPL fuel probably exists on the water table within the zone of venting influence at the bioventing study area.

3.0 PILOT TEST RESULTS

Parsons ES conducted soil air permeability tests and *in situ* respiration tests at both sites from October 3-7, 1994. As discussed in Section 2.2, pre-test soil gas samples

were collected for qualitative (field screening) analyses and quantitative (laboratory) analyses prior to conducting the tests. Test procedures and results for each site are discussed in the following sections.

3.1 Initial Soil Gas Chemistry

3.1.1 Site FT-01 Soil Gas Chemistry

Prior to initiating any air injection, the VMPs were purged until oxygen concentrations had stabilized. Initial baseline O_2, CO_2, and TVH concentrations were then measured using portable gas analyzers. Soil gas measurements were not obtained from SH2-MPC-8 or SH2-MPD-8 due to water in the VMP screens.

In contaminated soils, microorganisms had utilized available soil gas O_2 in all the VMPs and in the VWs. Initial soil gas O_2 concentrations were unexpectedly higher in the deeper soils (8-foot depth) than in the shallow soils (3 to 4.5-foot depth). These soil gas O_2 variations probably reflect the degree of residual TRPH soil contamination with depth, although vapor-phase TVH concentrations were actually higher in the deeper zones. Soil gas CO_2 concentrations in contaminated soils ranged from 6.5 to 10 percent.

Background soil gas O_2 concentrations outside the zone of contamination was 18.8 percent at a depth of 8 feet in SH2-BG1. Initial soil gas chemistry results (O_2, CO_2, TVH, temperature) obtained by field screening are listed in Table 3.1.

3.1.2 Site SS-15 Soil Gas Chemistry

Prior to initiating air injection, all VMPs and the VW were purged until oxygen concentrations had stabilized. Initial O_2, CO_2, and TVH concentrations were then measured using portable gas analyzers. Soil gas screening included a nearby piezometer (PZ-604) and groundwater monitoring well (MW-607) that were temporarily converted to VMPs. Piezometer PZ-605 was abandoned during the UST removals and could not be used as a VMP as proposed in the Draft Work Plan.

In contaminated soils, indigenous microorganisms had depleted soil gas O_2 concentrations to 0 percent in the VMPs, MW-607, and PZ-604. Soil gas O_2 concentration at SH1-VW1 was depressed to 4.4 percent. Initial soil gas chemistry results (O_2, CO_2, TVH, temperature) obtained by field screening are listed in Table 3.2. TRPH data are also provided to demonstrate the relationship between oxygen levels and residual fuel contamination in the soils. Oxygen-depleted soil gas at several of the VMPs is probably attributed more to vapor-phase contamination than to residual soil TRPH contamination.

Background soil gas conditions could not be established within the POL Depot due to high levels of soil vapor contamination. Representative background soil gas conditions were measured in groundwater monitoring well MW-19A near the Automotive Repair Shop at OU-2A. Background soil gas O_2 concentrations at the background well was 15.9 percent within the unsaturated screened interval from 23.66-28.75 feet bgs. A respiration test was performed on this well in November, 1994 (see Section 3.4)

TABLE 3.1

INITIAL SOIL GAS CHEMISTRY
IRP SITE FT-01
SHAW AFB, SOUTH CAROLINA

Sample Location	Depth (ft)	O_2 (%)	CO_2 (%)	TVH (ppmv)[a]	TRPH (mg/kg)[b]	Temp. (°F)
MPA	8.0	9.2	9.0	>10,000	NA	74.0
MPB	8.0	6.2	10.0	>10,000	NA	73.7
MPC	8.0	NM[c]	NM[c]	NM[c]	6,310	NA
MPD	8.0	NM[c]	NM[c]	NM[c]	NA	NA
MPA	4.5	2.7	9.9	180	3,750 (5.5')	NA
MPB	4.0	0.2	9.9	1,800	NA	73.8
MPC	3.0	0.5	9.5	7,200	NA	NA
MPD	3.0	0.1	9.5	1,000	NA	73.7
MP-BG1	8.0	18.8	2.5	16	NA	NA
VW-1	7.5*	7.0	8.7	>10,000	NA	NA
VW-2	7.5*	11.0	6.5	>10,000	3,350	NA

a/ GasTech hydrocarbon analyzer field screening results, parts per million by volume.
b/ Laboratory results for soils TRPH analyses, milligrams per kilogram.
c/ NM = Not sampled due to water in VMP well screen.
NA = Not analyzed, sampled or measured.
* Sample depth shown for VW is average depth to center of screen. Actual screened interval of VW is 5.5 feet to 9.5 feet bgs.

TABLE 3.2

INITIAL SOIL GAS CHEMISTRY
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

Sample Location	Depth (ft)	O_2 (%)	CO_2 (%)	TVH (ppmv)[a/]	TRPH (mg/kg)[b/]	Temp. (°F)
MPA	38	0	8.9	>20,000	1,880	65.6
MPB	38	0	8.3	>20,000	923	65.7
MPC	38	0	8.9	>20,000	NA	NA
MPA	24	0	11.5	>20,000	NA	66.8
MPB	24	0	11.5	>20,000	NA	NA
MPC	20	0	11.3	13,200	NA	NA
MPA	12	0	11.3	>20,000	NA	71.0
MPB	10	0	6.1	6,000	NA	71.6
VW-1	26.5[(1)]	4.4	7.2	>20,000	4,280 (40')	NA
MW-607	36.9[(2)]	0	9.2	>20,000	NA	NA
PZ-604	40.0[(3)]	0	10.0	8,000	NA	NA

a/ GasTech hydrocarbon analyzer field screening results, parts per million by volume.
b/ Laboratory results for soils TRPH analyses, milligrams per kilogram.
NA Not analyzed, sampled or measured.
(1) Sample depth shown for VW-1 is average depth to center of screen. Actual screened interval of VW is 12 feet to 41 feet bgs.
(2) Exposed (unsaturated) screen interval at MW-607 was 30 feet to 43.8 feet bgs. Depth shown represents average depth to center of exposed screen.
(3) Unsaturated screen interval at PZ-604 was 38 feet to 42.1 feet bgs. Depth shown represents average depth to center of exposed screen.

3.2 Air Permeability Test Results

3.2.1 Site FT-01 Air Permeability Tests

Two soil air permeability tests were conducted at Site FT-01 according to protocol procedures. The first test was conducted on October 5, 1994 by injecting air into vent well SH2-VW1. The second test was conducted on October 6, 1994 by injecting air into vent well SH2-VW2. Air injection was accomplished for both tests using a Gast model 2067 rotary vane blower. During both tests, pressure responses were measured at multiple depths in the surrounding VMPs using either a digital manometer or Magnehelic pressure gauges.

3.2.1.1 Air Permeability Test #1

During the first test, a portion of the air was bypassed through a pressure relief valve and the remaining air was injected into SH2-VW1 at an initial flow rate of 6.8 cubic feet per minute (cfm) and a corresponding VW pressure of 8.3 pounds per square inch (psi). An extreme pressure gradient was established between the VW and surrounding VMPs, with negligible pressure responses at the VMPs. Since meaningful dynamic pressure responses could not be measured, air injection was continued until steady-state conditions were maintained. Approximate steady-state pressure conditions were reached after 75 minutes at an injection flow rate of 7.0 cfm and VW injection pressure of 8 psi.

After the steady-state pressure conditions were measured, the blower continued operating and a series of three pneumatic step-down permeability tests were performed on SH2-VW1. The pneumatic step-down tests were conducted by decreasing the injection pressure in increments and measuring the corresponding flow rate for each pressure increment. The purpose of a pneumatic step-down test is to establish a blower performance curve for the soils being tested so that a properly-sized blower is selected for extended testing at the site.

Soil gas permeabilities were calculated using the HyperVentilate[R] model. Dynamic pressure measurements were not collected during the first air permeability test, therefore pressure response data were evaluated using only the steady-state solution. The soil permeability (k) value obtained from the steady-state equation was 0.61 darcys. This estimated permeability value is typical for a fine sand soil matrix but it is about one order of magnitude higher than expected for a clayey sand. The heterogeneous nature of soils at this site could produce a wide range of permeability values and the calculated steady-state value represents an average of the various soil types.

Air permeability testing at SH2-VW1 indicates that a soil pressure response can be induced at a distance of up to 30 feet. Approximate steady-state pressure at SH2-MPC-3 (r=30 feet) was 0.025 inches of water. At SH2-MPA (r=10 feet), steady-state pressure responses were 0.56 inches of water (4.5-foot depth) and 4.97 inches of water (8-foot depth). This demonstrates the extreme pressure gradient created in the soils during the test, since the air injection pressure at SH2-VW1 was 8 psi (221 inches of water). Parsons ES noted that several inches of rainfall occurred two days before the first air permeability test, which may have temporarily reduced the apparent

permeability of the soils. Extended air injection is expected to dry the soils and thereby improve their relative permeability.

3.2.1.2 Air Permeability Test #2

A second air permeability test was conducted at Site FT-01 to determine if better performance could be achieved at vent well SH2-VW2. The second test began with an air injection flow rate of 12.3 cfm at a VW pressure of 6.2 psi (172 inches of water). After one hour of injection, the VW pressure had dropped to 5.2 psi and the flow rate was unchanged. After four hours of continuous air injection, the VW pressure had reduced to 4.2 psi and the flow rate remained unchanged at 12.3 cfm. Approximate steady-state conditions were achieved at most of the VMPs after one hour. However, slight pressure increases were occurring in the deeper VMPs after four hours of injection as the soils dried out and the relative permeability continued to improve. A pressure response of 0.08 inches of water was achieved at SH2-MPD-3 (r=30.4 feet) during this time period. Results of the second air permeability test at Site FT-01 are presented in Table 3.3.

Soil gas permeabilities were calculated for the second test using the HyperVentilate^R model. Pressure response data were evaluated using solutions from both dynamic and steady-state equations. Two steady-state solutions were derived, one for the early portion of the test (VW pressure=6.2 psi) and one for the end of the test (VW pressure=4.2 psi). The early-time calculation produced an air permeability value of 1.42 darcys. An air permeability value of 2.13 darcys was derived for approximate steady-state conditions at the end of the test. Both values are reasonable for a fine to medium sand soil matrix.

Soil permeability (k) values by the dynamic solution were derived from data collected until approximate steady-state conditions were achieved. Data from the deeper VMPs produced air permeability values ranging from 8.49 darcys (SH2-MPB-8) to 8.99 darcys (SH2-MPA-8). These estimated darcy values are still one to two orders of magnitude greater than values expected for the clayey sand soil matrix. Lithologic descriptions and the extreme pressure gradient observed during air permeability testing suggest that the steady-state permeability values of 1.42 to 2.13 darcys are probably more accurate for this site.

Better air permeability results were achieved at SH2-VW2 than at SH2-VW1. Testing demonstrated that air can be injected into SH2-VW2 at a higher flow rate and lower pressures. The radius of pressure influence appears to be slightly greater for well SH2-VW2 due to its increase air flow capacity. Pressure responses from both tests indicate that the shallow soils are more permeable than the deep soils. These apparent soil permeability variations are not uncommon for a heterogeneous soil.

3.2.2 Site SS-15 Air Permeability Test

A soil air permeability test was conducted at Site SS-15 according to protocol procedures. The test was conducted on October 4, 1994 by injecting air into vent well SH1-VW1. Air injection was accomplished using a Rotron model DR-505 centrifugal blower. Pressure responses were measured at multiple depths in the surrounding VMPs using either a digital manometer or Magnehelic pressure gauges. The time-pressure response data from the test are presented in Table 3.4.

TABLE 3.3

PRESSURE RESPONSE (inches of water)
AIR PERMEABILITY TEST
IRP SITE FT-01
SHAW AFB, SOUTH CAROLINA

Depth (feet bgs)	MPA		MPB		MPC		MPD	
	4.5'	8'	4'	8'	3'	8'	3'	8'
Elapsed Time (min: sec)								
00:30	0	0	-	-	0.07	0	0	--
1:00	0	0	0.06	0.06	0.21	<0	0	--
1:30	0.03	0.01	-	-	0.29	<0	0.01	--
2:00	0.03	0.01	0.10	0.19	0.33	<0	-	--
2:30	-	-	-	-	0.35	<0	0.01	--
3:00	0.05	0.01	0.13	0.25	0.37	<0	-	--
4:00	0.05	0.01	0.14	0.28	0.39	<0	0.01	--
5:00	0.05	0.01	0.15	0.30	0.41	<0	-	--
5:30	-	-	-	-	-	-	-	--
6:00	-	-	0.15	0.32	0.42	<0	0.01	--
7:00	0.05	-	0.15	0.32	0.42	<0	-	--
8:00	-	0.03	0.16	0.33	0.43	<0	-	--
9:00	-	-	0.16	0.33	0.44	<0	0.02	--
10:00	0.05	0.04	0.16	0.34	0.44	<0	-	--
11:00	-	-	-	-	-	-	-	--
12:00	-	-	-	-	-	-	0.02	--
13:00	-	0.06	-	-	0.46	<0	-	--
14:00	0.04	-	-	-	-	-	0.02	--
16:00	-	-	0.16	0.33	-	-	-	--
18:00	-	0.09	0.17	0.36	0.47	<0	-	--
20:00	0.04	0.1	0.18	0.38	-	-	0.02	--
22:00	-	-	-	-	0.49	<0	-	--
24:00	-	-	-	0.40	-	-	-	--
26:00	-	-	-	-	-	-	0.04	--
28:00	-	-	-	-	-	-	-	--
30:00	0.04	0.1	0.18	0.47	0.51	<0	0.04	--
32:00	-	-	-	-	-	-	-	--
35:00	-	0.15	-	-	0.52	<0	0.05	--
37:00	-	-	-	-	-	-	-	--
40:00	0.05	0.18	-	-	0.53	<0	0.06	--
45:00	0.05	0.22	0.20	0.75	-	-	0.06	--
50:00	0.05	0.26	-	-	0.54	-	0.06	--
55:00	0.05	0.30	-	-	-	-	0.06	--
60:00	0.055	0.42	0.20	1.00	0.55	-	0.06	--
240:00	0.05	1.75	0.24	1.59	0.67	-	0.08	--

The air permeability test was conducted by injecting air into SH1-VW1 at a flow rate of 66 cfm and a VW pressure of 56 inches of water. The injection pressure and flow rate remained relatively constant throughout the test. Steady-state conditions were achieved in all VMPs except PZ-604 within 45 minutes of starting the test. Within 10 minutes of starting the test, pressure responses were measured in PZ-604 at a distance of 107.5 feet from the VW. Final steady-state readings were recorded at the VMPs after 60 minutes of injection, then the blower was allowed to run for another 20 minutes to monitor the soil gas oxygen influence from short-term air injection.

Soil gas permeabilities were calculated for the test using the HyperVentilate^R model. Pressure response data were evaluated using both dynamic and steady-state equations. An air permeability value of 4.46 darcys was derived for approximate steady-state conditions near the end of the test. This permeability value represents an average for all soil lithologies within the soil venting zone of influence.

Permeability values were calculated for each VMP screen interval using the dynamic equation of the HyperVentilate^R model. These values ranged from 10.8 darcys at SH1-MPA-12 to 294.1 darcys at SH1-MPB-38. While these values appear to be slightly overestimated, they are not unreasonable for the soil types found at each VMP screen interval. The general trend of these results shows that the soil air permeability increases with depth by at least one order of magnitude between the shallowest VMP screens and the deepest VMP screens. The permeability values may be slightly overestimated because the total air flow injected through the VW screen and used in the calculations does not represent the actual air flow contributed to each lithologic unit. Considering these factors and the test results, Parsons ES estimates that the average permeability of the upper silty sand unit ranges from 1 to 10 darcys and the average permeability of the lower coarse sand unit ranges from 20 to 200 darcys.

The radius of pressure influence was relatively large at this site, especially within the deep coarse sand unit that contains the water table. A pressure response of 0.35 inches of water was measured in PZ-604 after one hour of air injection, indicating that the pressure radius of influence exceeded 107.5 feet in the deeper soils. The steady-state pressure response at MW-607, located 44.8 feet from the VW, was 2.60 inches of water.

3.3 Oxygen Influence and Distribution

The depth and radius of oxygen increase in the subsurface resulting from air injection into the VW during pilot testing is the primary design parameter for full scale bioventing systems. Optimization of full-scale VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Soil pressure responses measured during the air permeability test do not necessarily equate to soil gas flow when determining an effective radius of oxygen influence. The ability to actually transport gases (oxygen) through the soil column is far more important in a bioventing design than the ability to create a pressure response in the soil. At both test sites, soil gas composition (O_2, CO_2, TVH) was measured at the VMPs during the air permeability tests and at system startup to monitor the diffusion of injected air (oxygen) outward from the injection VW. These results are presented in the following sections.

TABLE 3.4

PRESSURE RESPONSE (inches of water)
AIR PERMEABILITY TEST
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

Depth (feet bgs)	MPA			MPB			MPC		MW-607	PZ-604
	12'	24'	38'	10'	24'	38'	20'	38'	(30'-43.8')	(38'-42')
Elapsed Time (min: sec)										
00:30	0	0	4	0	0.25	2.0	0.01	0.06	0.0	---
1:00	0	0.1	6.2	0	0.5	3.5	0.08	0.49	0.10	---
1:30	---	---	---	0.25	0.75	4.5	0.18	0.86	0.20	---
2:00	0.5	1.5	8.3	0.25	1.0	5.0	0.28	1.17	0.50	---
2:30	---	---	---	0.50	1.5	5.5	0.39	1.42	0.70	---
3:00	1.0	1.5	9.0	0.50	1.75	6.0	0.51	1.65	0.90	---
4:00	1.5	2.0	9.8	0.75	2.0	6.5	0.73	1.99	1.20	---
5:00	1.9	2.3	10.0	1.0	2.0	6.75	0.89	2.24	1.40	0
5:30	---	---	---	---	---	---	0.98	2.34	1.60	---
6:00	2.0	2.5	10.0	1.0	2.25	7.0	1.04	2.43	1.70	---
7:00	2.0	2.5	10.0	1.0	2.5	7.0	1.15	2.57	1.80	---
8:00	2.0	2.6	10.1	1.0	2.75	7.25	1.25	2.69	1.90	---
9:00	2.2	3.0	10.2	1.25	2.75	7.25	1.33	2.79	2.00	---
10:00	2.5	3.0	10.3	1.50	2.75	7.25	1.39	2.87	2.00	0.10
11:00	---	---	---	---	---	---	1.44	2.93	2.10	---
12:00	2.7	3.1	10.5	1.50	2.75	7.5	1.49	3.00	2.20	---
13:00	---	---	---	---	---	---	1.53	3.04	2.20	---
14:00	2.9	3.1	10.7	1.50	3.0	7.5	1.56	3.09	2.30	---
16:00	---	---	---	1.50	3.0	7.5	1.63	3.16	2.40	0.17
18:00	2.9	3.3	11.0	1.50	3.0	7.75	1.66	3.20	2.40	---
20:00	2.8	3.3	10.9	1.75	3.0	7.75	1.69	3.24	2.40	0.24
22:00	---	---	---	---	---	---	1.71	3.26	---	---

TABLE 3.4 (CONTINUED)

PRESSURE RESPONSE (inches of water)
AIR PERMEABILITY TEST
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

Depth (feet bgs)	MPA			MPB			MPC		MW-607	PZ-604
	12'	24'	38'	10'	24'	38'	20'	38'	(30'-43.8')	(38'-42')
Elapsed Time (min: sec)										
24:00	---	---	---	---	---	---	1.74	3.30	---	---
26:00	---	---	---	1.75	3.0	7.75	1.75	3.32	2.50	---
28:00	3.0	3.3	11.0	---	---	---	1.75	3.32	---	---
30:00	---	---	---	1.75	3.25	7.75	1.75	3.32	2.50	---
32:00	---	---	---	---	---	---	---	---	---	---
35:00	2.9	3.5	11.0	1.75	3.25	7.75	1.75	3.32	2.50	0.26
37:00	---	---	---	---	---	---	---	---	---	---
40:00	---	---	---	---	---	---	1.77	3.35	2.55	---
45:00	3.0	3.6	11.0	1.75	3.25	8.00	1.78	3.37	2.60	0.33
50:00	---	---	---	---	---	---	1.78	3.40	2.60	---
55:00	---	---	---	---	---	---	1.77	3.39	2.60	---
60:00	3.0	3.6	11.0	1.75	3.25	8.00	1.75	3.38	2.60	0.35

3.3.1 Oxygen Influence at Site FT-01

Subsurface oxygen transport was very limited during the first air permeability test conducted on SH2-VW1. After 100 minutes of air injection into SH2-VW1, O_2 had increased from 0.9 percent to 11.2 percent at SH2-MPA-4.5 and from 5.8 percent to 6.0 percent at SH2-MPB-8. Oxygen decreases were measured in SH2-MPB-4 and in SH2-MPA-8 at the same time. Soil gas composition in the remaining VMPs was unchanged. The O_2 decreases observed at two VMP intervals is probably the result of oxygen-defficient soil gas being slowly transported or diffused away from the VW. These data indicate that during the first air permeability test, O_2 moved outward no more than 20 feet from SH2-VW1 and the only significant O_2 increases occurred in shallow soils within 10 feet of the VW. Table 3.5 summarizes the changes in soil gas oxygen concentrations that occurred during both air permeability tests.

Oxygen transport was much more successful during the second air permeability test using SH2-VW2. After 250 minutes of air injection, O_2 concentrations had increased significantly in all functioning VMPs except SH2-MPD-3. The deeper VMPs showed O_2 increases from 13.0 percent to 13.5 percent at SH2-MPA-8 and from 5.9 percent to 10.5 percent at SH2-MPB-8. The shallow VMPs had oxygen increases ranging from 2.3 percent to 14.0 percent. These data, summarized in Table 3.5, show that injected oxygen (air) moved over 30 feet during the second air permeability test.

Parsons ES also monitored O_2 influence during the system startup for extended operation (November, 1994). Both VWs at Site FT-01 were receiving air injection during the system startup. After 29 hours of system operation, O_2 increases were observed in all shallow VMPs except for SH2-MPD-3. The deeper VMP screens all contained water at that time and their soil gas composition could not be monitored. The following O_2 increases were observed at the shallow VMPs: 2.7 percent to 3.5 percent (SH2-MPA-4.5); 0.1 percent to 9.5 percent (SH2-MPB-4); and 0.2 percent to 19.3 percent (SH2-MPC-3). These results demonstrate that vent well SH2-VW2 contributes most of the subsurface O_2 delivery when both VWs are operated simultaneously.

3.3.2 Oxygen Influence at Site SS-15

During the air permeability test at Site SS-15, O_2 concentrations were measured at the end of the test after 80 minutes of air injection. As summarized in Table 3.6, soil gas O_2 concentrations increased only in the deepest screen interval of the two VMPs located closest to the VW. Oxygen levels increased from 0 percent to 17.5 percent at SH1-MPA-38 and from 0 percent to 18.5 percent at SH1-MPB-38 during the test. These results demonstrate that O_2 is preferentially transported through the highly permeable lower sand unit compared to the overlying, less permeable lithologic units. Additionally, these results show that O_2 transport in the deeper sand unit was greater than 20 feet but less than 34.6 feet after 80 minutes of injection.

Parsons ES monitored O_2 influence during system startup to obtain soil gas conditions more representative of long-term air injection. Several soil gas measurement events were conducted to monitor O_2 influence and to adjust the blower system for optimum long-term performance. Soil gas O_2 had increased significantly in all VMPs after 15.6 hours (935 minutes) of air injection in SH1-VW1 at an average

TABLE 3.5

INFLUENCE OF AIR INJECTION AT VENT WELLS ON MONITORING POINT OXYGEN LEVELS IRP SITE FT-01 SHAW AFB, SOUTH CAROLINA

Air Injection Into VW-1 (Test #1)

VMP	Distance From VW-1 (ft)	Depth (ft)	Initial O_2 (%)[a/]	Final O_2 (%)[b/]
MPA	10	8.0	9.7	9.0
MPB	20.4	8.0	5.8	6.0
MPA	10	4.5	0.9	11.2
MPB	20.4	4.0	11.3	9.5

a/ Initial O_2 readings represent conditions at the end of respiration testing. Not all VMP soil gas O_2 concentrations were at equilibrium baseline levels prior to beginning air permeability test.

b/ Readings taken at the end of air permeability test after 100 minutes of air injection into VW-1.

Air Injection Into VW-2 (Test #2)

VMP	Distance From VW-2 (ft)	Depth (ft)	Initial O_2 (%)[c/]	Final O_2 (%)[d/]
MPA	30	8.0	13.0	13.5
MPB	19.6	8.0	5.9	10.5
MPC	10	8.0	NM	NM
MPD	30.4	8.0	NM	NM
MPA	30	4.5	0	14.0
MPB	19.6	4.0	0.6	2.9
MPC	10	3.0	7.9	13.6
MPD	30.4	3.0	0	0

c/ Initial O_2 readings represent conditions at the end of respiration testing and prior air permeability test on 10-5-94 (injecting into VW-1). Soil gas O_2 concentrations were elevated above equilibrium baseline levels in MPA-8 and MPC-3 due to prior tests.

d/ Readings taken at the end of air permeability test after 250 minutes of air injection into VW-2.

NM = Not measured

TABLE 3.6

INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

Air Permeability Test Monitoring Results

VMP	Distance From VW-1 (ft)	Depth (ft)	Initial O_2 (%)[a/]	Final O_2 (%)[b/]
MPA	11.5	38	0	17.5
MPB	20	38	0	18.5
MPC	34.6	38	0	0
MPA	11.5	24	0	0
MPB	20	24	0	0
MPC	34.6	20	0	0
MPA	11.5	12	0	0
MPB	20	10	0	0
MW-607	44.8	36.9[(1)]	0	0

a/ Initial O_2 readings represent equilibrium soil gas conditions prior to air permeability test.
b/ Readings at end of air permeability test after 80 minutes of air injection into VW-1 at 66 cfm.
(1) Represents center of unsaturated well screen.

System Start-Up Monitoring Results

VMP	Distance From VW-1 (ft)	Depth (ft)	Initial O_2 (%)[c/]	Final O_2 (%)[d/]
MPA	11.5	38	0.8	20.5
MPB	20	38	0.6	20.4
MPC	34.6	38	0.7	19.5
MPA	11.5	24	0.8	19.2
MPB	20	24	0.7	19.0
MPC	34.6	20	0.6	5.8
MPA	11.5	12	0.8	17.5
MPB	20	10	3.0	8.2

c/ Initial O_2 readings represent equilibrium soil gas conditions prior to starting the blower for extended operations on 11/18/94.
d/ Readings during system startup monitoring after 15.6 hours (935 minutes) of air injection into VW-1 at 36 cfm.

flow rate of 36 cfm. Oxygen increases ranged from a low of 5.2 percent (SH1-MPB-10 and SH1-MPC-20) to a high of 19.8 percent at SH1-MPB-38. These results are also summarized in Table 3.6 to illustrate the differences in soil gas O_2 levels versus elapsed time of air injection.

3.4 *In Situ* Respiration Tests

In situ respiration tests were conducted at both bioventing sites from October 3-7, 1994. The background respiration test for Site SS-15 (using well MW-19A) was conducted from November 18-19, 1994. Respiration testing was conducted in accordance with procedures outlined in the bioventing protocol document referenced in the work plan submitted by Parsons ES. Testing procedures included helium injection into the VMPs for use as a tracer to test for air leaks. The test methods and results for each site are summarized in the following sections.

3.4.1 Site FT-01 Respiration Tests

Air with a 2.1 to 4.7 percent helium mixture was injected for 18 hours into all the VMPs that did not contain water. Air injection into the VMPs also increased the O_2 concentration at adjacent vent well SH2-VW1 from 7.0 to 19.1 percent after 18 hours. *In situ* respiration testing was conducted on this VW but the O_2 utilization results were anomalously high, indicating that soils around the VW screen were probably not oxygen-saturated before the test began. Background respiration testing was not conducted because the background VMP (MP-BG1-8) contained initial O_2 levels of 18.8 percent, indicating that abiotic and/or non-fuel oxygen uptake was not a factor at this site.

Oxygen uptake and CO_2 production were monitored for 46 hours during the respiration tests. Appendix B contains the field data plots of O_2 utilization and helium obtained during the test. Oxygen was readily utilized by indigenous soil microorganisms, indicating microbial fuel degradation can be stimulated at the site by oxygen enhancement. Referencing the data plots in Appendix B , the "k" values shown on the graphs are the estimated oxygen utilization rates that are used to calculate fuel biodegradation rates. Oxygen utilization rates at the multi-depth VMPs ranged from a low of 0.004 percent per minute (SH2-MPB-8 and SH2-MPC-3) to a high of 0.013 percent per minute (SH2-MPA-4.5). Table 3.7 provides a summary of the oxygen utilization rates for Site FT-01. Results from SH2-VW1 are not included in this table.

A consistent helium injection rate could not be maintained in the helium diffusion chamber due to diurnal changes in ambient temperature. Recovered helium concentrations showed wide variations in their trends. Some of the recovered helium concentrations were relatively constant, while others showed either cyclic fluctuations or apparent minor losses throughout the monitoring period. Although some of the helium monitoring results were not conclusive, the relatively constant helium levels at the other VMPs indicated that little O_2 was lost from the soil due to outward diffusion.

The magnitude of biological oxygen utilization and fuel degradation can be estimated based on the initial pilot test results. Background soil gas conditions suggest that abiotic and non-fuel oxygen uptake is insignificant at Site FT-01. Assuming that no abiotic or non-fuel O_2 uptake occurred during the respiration tests, the observed O_2

TABLE 3.7

APPARENT OXYGEN UTILIZATION RATES
IRP SITE FT-01
SHAW AFB, SOUTH CAROLINA

VMP	Test Duration (min)	Apparent O_2 Utilization (%/min)
MPA-4.5	1,620	0.013
MPA-8	2,770	0.005
MPB-4	2,750	0.007
MPB-8	2,750	0.004
MPC-3	2,750	0.004
MPD-3	2,750	0.01

utilization rates indicate that between 951 to 2,197 milligrams of hydrocarbons per kilogram of soil can be biodegraded per year at this site. The VMP biodegradation rate estimates are based on average air-filled porosities of 0.105 to 0.084 liters per kilogram of soil, and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel biodegraded. Actual biodegradation rates can be highly localized and may be affected by temperature, soil moisture, fuel (carbon) concentrations, and other factors.

3.4.2 Site SS-15 Respiration Tests

Air with a 1.6 to 9.0 percent helium mixture was injected for 23 hours into all VMPs used for respiration testing. The air injection rates ranged from 0.75 to 1.2 cfm at each injection point. Air injection for *in situ* respiration testing was not conducted on the VW.

Oxygen uptake and CO_2 production were monitored for 31 hours during the respiration tests. Appendix C contains the field data plots of O_2 utilization and helium obtained during the test. Oxygen utilization by indigenous soil microorganisms was moderate at this site. Referencing the data plots in Appendix C, the "k" values shown on the graphs are the estimated oxygen utilization rates that are used to calculate fuel biodegradation rates. Oxygen utilization rates at the multi-depth VMPs ranged from a low of 0.0009 percent per minute at SH1-MPB-38 to a high of 0.006 percent per minute at SH1-MPA-12. Table 3.8 provides a summary of the oxygen utilization rates for Site SS-15.

A consistent helium injection rate could not be maintained in the helium diffusion chamber due to diurnal changes in ambient air temperatures. Recovered helium concentrations were relatively constant at some of the VMPs, while others showed an apparent helium loss. The inconsistent helium injection rate may have contributed to these effects. Helium monitoring was not conclusive for this site, but it is unlikely that significant O_2 was lost from the soil due to diffusion.

A background respiration test was conducted on well MW-19A at OU-2A, located upgradient from the POL Depot. This well is completed in a different stratigraphic unit (Lang Syne Formation), but the soil characteristics are similar to those of the Duplin Formation encountered at the POL Depot. The baseline soil gas O_2 level at MW-19A was 15.9 percent. Using the respiration test methods previously described (without helium), the O_2 concentration was increased to 21.0 percent at the well. Oxygen uptake and CO_2 production were monitored for 15.5 hours. During this time the soil O_2 level dropped a negligible 0.2 percent, indicating that background abiotic and/or non-fuel oxygen uptake was not a factor in these soils.

The magnitude of biological oxygen utilization and fuel degradation can be estimated based on the initial pilot test results. Background respiration testing suggests that abiotic and non-fuel oxygen uptake is not a factor at Site SS-15. Assuming that no abiotic or non-fuel O_2 uptake occurred during the respiration tests, the observed O_2 utilization rates indicate that between 81 to 1,099 milligrams of hydrocarbons per kilogram of soil can be biodegraded per year at this site. The VMP biodegradation rate estimates are based on average air-filled porosities of 0.045 to 0.084 liters per kilogram of soil, and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel biodegraded.

TABLE 3.8

APPARENT OXYGEN UTILIZATION RATES
IRP SITE SS-15 (POL DEPOT)
SHAW AFB, SOUTH CAROLINA

VMP	Test Duration (min)	Apparent O_2 Utilization (%/min)
MPA-12	1,850	0.006
MPA-24	1,850	0.002
MPA-38	1,850	0.004
MPB-10	1,860	0.004
MPB-24	1,860	0.002
MPB-38	1,860	0.0009
MPC-20	1,870	0.002
MPC-38	1,870	0.002
MW-607	1,880	0.001

Although the O_2 utilization and biodegradation rates were lower at this site, the data summarized in Table 3.8 indicate that microbial fuel degradation can be stimulated by oxygen enhancement. One disadvantage to the bioventing test at this site is that the VMPs and VW had to be relocated to areas with much less residual TPH soil contamination than is present in the UST source areas. Much of the O_2 utilization is attributed to biodegradation of vapor-phase hydrocarbons outside of the grossly-contaminated areas. The highest O_2 utilization rates were actually achieved in shallow soils closest to the former 1,000-gallon UST excavation. Higher respiration O_2 utilization rates should be expected in soils having elevated residual TPH concentrations.

3.5 Potential Air Emissions

The highest soil vapor total BTEX concentration of 945 ppmv and benzene concentration of 410 ppmv occurred in deeper soils at Site SS-15. These data suggest that potential benzene or BTEX air emissions during bioventing should not be a concern at these sites.

While routinely monitoring ambient air quality during the air permeability tests, Parsons ES did not detect any hydrocarbon vapors being emitted to the atmosphere. Some minor losses of VOCs to the atmosphere are possible at Site FT-01 during bioventing due to the shallow nature of the soil contamination. Potential VOC emissions that may occur at Site FT-01 should rapidly decrease as accumulated vapors move outward from the injection point and are biodegraded as they move through the soil. The potential for VOC emissions is even less at Site SS-15 because the depth of air injection is much greater. Additionally, long-term air flow rates into the individual VWs are less than those used during the air permeability tests, while still maintaining an adequate radius of oxygen influence at each site. Reduced injection flow rates will further minimize potential VOC emissions.

4.0 RECOMMENDATIONS

Initial field testing at both sites has demonstrated that oxygen has been depressed or depleted in the contaminated soils and that aerobic fuel biodegradation can be stimulated at each site by the introduction of oxygen. Planned SVE operations at Site SS-15 will also stimulate oxygen movement in the subsurface that should enhance aerobic biodegradation of less volatile hydrocarbons. The Air Force Center for Environmental Excellence (AFCEE) recommended that air injection be initiated at both sites to determine the long-term radii of oxygen influence and the effects of time, available nutrients, and changing temperatures on fuel biodegradation rates.

Permanent blowers have been installed at each site to provide air injection for the one-year pilot studies. The blowers began operation for the one-year tests on November 18, 1994. Adjustments were made to each system at startup to optimize air injection flow rates and pressures. At Site FT-01, the combined operating flow rate for both VWs was 17.2 cfm at a total system pressure of 3.7 psi. Pressures at the individual VWs were 2.4 psi (SH2-VW1) and 1.7 psi (SH2-VW2). At Site SS-15, the system was adjusted to an operating air flow rate of 27 cfm at 26 inches of water pressure.

After the systems have been operating for six months, Parsons ES will return to each site to perform a repeat respiration test and to measure the radius of oxygen influence. This schedule may have to be accelerated at Site SS-15 due to the planned construction and operation of a full-scale SVE system within the POL Depot. Preliminary design for the SVE system shows that at least one of the proposed SVE wells will interfere with future respiration testing at the bioventing VMPs. According to Shaw AFB, the SVE system may begin operation as early as March 1995. Bioventing activities will be coordinated with the proposed SVE project so that at least one repeat respiration test can be conducted prior to starting the SVE system.

After one year of operation, final soil samples and soil gas samples will be collected from each site, and final respiration tests will be conducted, to determine the degree of remediation achieved during the first year of *in situ* treatment. Again, the decision to perform final (one-year) sampling and testing at Site SS-15 will be based on the status of the SVE project and the potential SVE influence within the bioventing study area.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of two options for each site:

1. Upgrade the system, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling analytical results indicate significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved for the site.

5.0 REFERENCES

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frendt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*. Prepared for the Air Force Center for Environmental Excellence. May. Denver, Colorado.

Engineering-Science, Inc., 1992. *Field Sampling Plan for AFCEE Bioventing*. Denver, Colorado.

APPENDIX A

SOIL BORING LOGS
AND
WELL CONSTRUCTION RECORDS

SITE FT-01

NCWELL 12/02/1994 09:08:34

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client: AFCEE
Site: Shaw AFB, IRP Site FT-01
Project Identification Number: 722407-53050
Geol./Eng. Supervising Soil Boring: S.G. Watkins
Drilling Method (s): HSA
Sampling Method (s): 3" SS
Soil Boring Start Date: 07/28/94
Soil Boring Termination Date: 07/28/94
Drilling Company: Alliance Environmental
Borehole Diameter (inches): 10.5
Borehole Depth (feet below surface): 10.5
Surface Elevation (feet MSL): na
Top of Casing Elevation (feet MSL): na

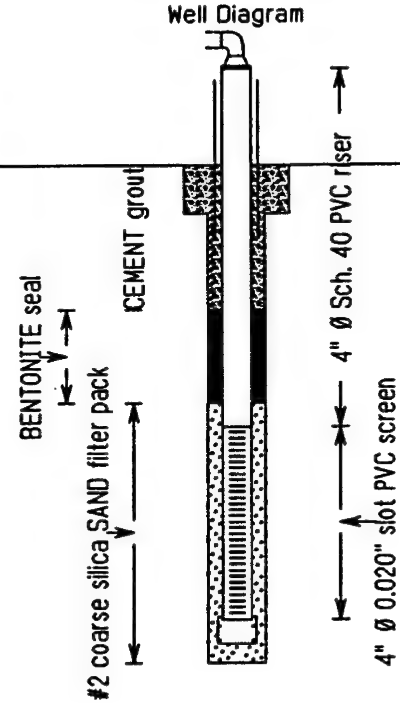
Soil Boring Identification Number: SH2-VW1
Well Identification Number: SH2-VW1
Geol./Eng. Supervising Well Installation: S.G. Watkins
Casing Installation Date: 07/28/94
Seal Grouting Date: 07/29/94
Casing Material: 4" dia. Sch. 40 PVC
Screen Material: 4" dia. 0.020" slot PVC
Casing Interval (feet below surface): -2 to 5.5
Screened Interval (feet below surface): 5.5 to 9.5
Total Well Depth (feet below surface): 10.4
Water Level Measurement Date: na
Depth to Water (feet below top of casing): na
Water Level Elevation (feet MSL): na

Comments: Protective outer (stickup) casing is 6" PVC.

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
0.0–4.0					Moderate yellow-brown (10YR5/4) to dark yellow-orange (10YR6/6) silty fine to medium SAND, fuel odor.	SP
4.0–6.0	X	13,7, 6,9	na	100	Dark yellow-orange (10YR6/6) silty to clayey fine to medium SAND grading into pale gray clayey fine to medium SAND, slightly cohesive, wet, fuel odor.	SM
7.0–9.0	X	20,27, 33,27	na	200	Pale gray (N7) to pale yellow-brown (10YR6/2) clayey fine to medium SAND, dense, cohesive, moist, fuel odor.	
10.5					*Soil boring was terminated at 10.5' below ground surface.*	

Depth scale (feet): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0

Well Diagram



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PARSONS ENGINEERING SCIENCE

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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HSA
Sampling Method (s) 3" SS
Soil Boring Start Date 07/28/94
Soil Boring Termination Date 07/28/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 10.5
Borehole Depth (feet below surface) 10.5
Surface Elevation (feet MSL) na
Top of Casing Elevation (feet MSL) na

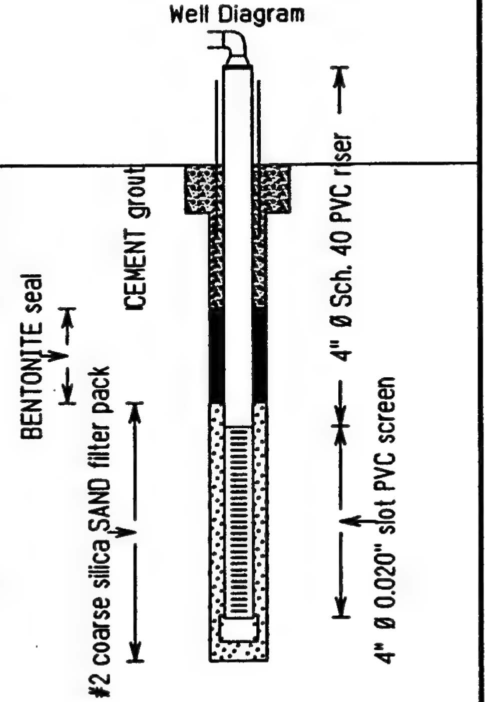
Soil Boring Identification Number SH2-VW2
Well Identification Number SH2-VW2
Geol./Eng. Supervising Well Installation S.G. Watkins
Casing Installation Date 07/28/94
Seal Grouting Date 07/29/94
Casing Material 4" dia. Sch. 40 PVC
Screen Material 4" dia. 0.020" slot PVC
Casing Interval (feet below surface) -2 to 5.5
Screened Interval (feet below surface) 5.5 to 9.5
Total Well Depth (feet below surface) 10.4
Water Level Measurement Date na
Depth to Water (feet below top of casing) na
Water Level Elevation (feet MSL) na

Comments: Protective outer (stickup) casing is 6" PVC.

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Dark gray (N3) to gray-brown (5YR3/2) silty fine to medium SAND, strong fuel odor and dark staining.	SP	
4.0					Clayey fine to medium SAND.	SM	
6.0	X	5,11, 12,20	na	230	Mottled medium-gray (N5) to brown (5YR5/2) clayey fine SAND, moist to wet, very strong fuel odor. Less clay at 6'.	SW	
8.0	X	8,11, 29,39	na	96	Gray (N5) silty to clayey f-m SAND, red to brown mottle, moist to wet, strg fuel odor.	SM	
10.0					Mottled red (5R4/6) to gray (N6) sandy CLAY, V dense, moist, moderate fuel odor.	CL	
					Soil boring was terminated at 10.5' below ground surface.		

Depth scale: 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

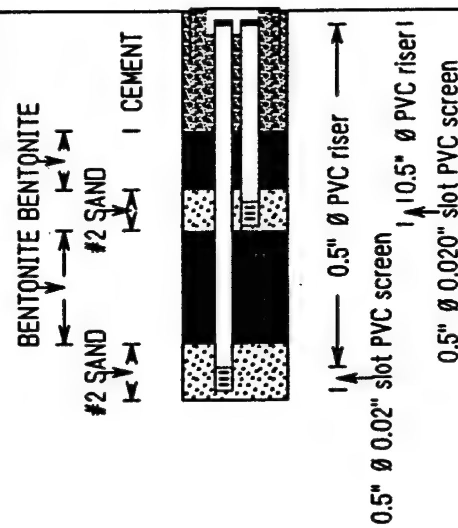
Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HA
Sampling Method (s) HA bucket
Soil Boring Start Date 07/28/94
Soil Boring Termination Date 07/28/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 4
Borehole Depth (feet below surface) 8.2
Deep Casing Installation Date 07/28/94
Deep Seal Grouting Date 07/28/94

Soil Boring Identification Number SH2-MPA
Well Identification Number SH2-MPA
Geol./Eng. Supervising Well Installation S.G. Watkins
Shallow Casing Installation Date 07/28/94
Shallow Seal Grouting Date 07/28/94
Deep Casing Material 0.5" dia. Sch. 80 PVC
Deep Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.5" dia. Sch. 80 PVC
Shallow Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 7.5
D. Screen Interval (feet below surface) 7.5 to 8
S. Casing Interval (feet below surface) 0.3 to 4
S. Screen Interval (feet below surface) 4 to 4.5

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Pale brown (5YR5/2) fine SAND, loose, no fuel odor.	SP	
2.0					Pale brown (5YR5/2) fine to medium SAND, well sorted, trace silt, loose, moist, slight fuel odor.		
	X	na	na	64			
4.0					Pale gray (N7) silty fine to medium SAND, moist. More fuel odor below 3.5'.	SM	
	X	na	na	420	Mottled pale blue-gray (5B7/1) to yellow-brown (10YR5/4) clayey fine to medium SAND, cohesive to friable, moist, very strong fuel odor and dark staining. Has zones of sandy to silty CLAY.	SM ML	
6.0							
8.0					*Soil boring was terminated at 8.2' below ground surface.*		
10.0							
12.0							
14.0							
16.0							
18.0							
20.0							
22.0							
24.0							

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

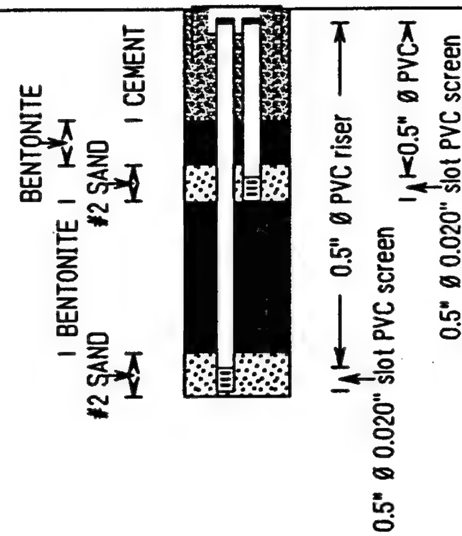
Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HA
Sampling Method (s) HA bucket
Soil Boring Start Date 07/28/94
Soil Boring Termination Date 07/28/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 4
Borehole Depth (feet below surface) 8.1
Deep Casing Installation Date 07/28/94
Deep Seal Grouting Date 07/28/94

Soil Boring Identification Number SH2-MPB
Well Identification Number SH2-MPB
Geol./Eng. Supervising Well Installation S.G. Watkins
Shallow Casing Installation Date 07/28/94
Shallow Seal Grouting Date 07/28/94
Deep Casing Material 0.5" dia. Sch. 80 PVC
Deep Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.5" dia. Sch. 80 PVC
Shallow Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 7.5
D. Screen Interval (feet below surface) 7.5 to 8
S. Casing Interval (feet below surface) 0.3 to 3.5
S. Screen Interval (feet below surface) 3.5 to 4

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Pale brown (5YR5/2) fine to medium SAND.	SP	
2.0					Medium gray (N5) silty fine to medium SAND, some fuel odor.	SW	
	X	na	na	160			
4.0					Very pale gray (N8) fine SAND, well sorted, very little silt, strong fuel odor.	SP	
6.0					Mottled pale blue-gray (5B7/1) to yellow-orange (10YR6/6) clayey fine to medium SAND, cohesive, moist, strong fuel odor.	SM	
	X	na	na	1200			
8.0					*Soil boring was terminated at 8.1' below ground surface.*		
10.0							
12.0							
14.0							
16.0							
18.0							
20.0							
22.0							
24.0							

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

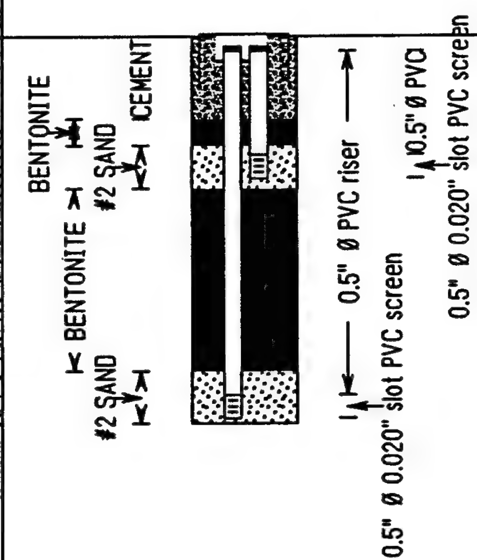
Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HA
Sampling Method (s) HA bucket
Soil Boring Start Date 07/28/94
Soil Boring Termination Date 07/28/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 4
Borehole Depth (feet below surface) 8.1
Deep Casing Installation Date 07/28/94
Deep Seal Grouting Date 07/28/94

Soil Boring Identification Number SH2-MPC
Well Identification Number SH2-MPC
Geol./Eng. Supervising Well Installation S.G. Watkins
Shallow Casing Installation Date 07/28/94
Shallow Seal Grouting Date 07/28/94
Deep Casing Material 0.5" dia. Sch. 80 PVC
Deep Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.5" dia. Sch. 80 PVC
Shallow Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 7.5
D. Screen Interval (feet below surface) 7.5 to 8
S. Casing Interval (feet below surface) 0.3 to 2.5
S. Screen Interval (feet below surface) 2.5 to 3

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Moderate brown (5YR3/4) to pale brown (5YR5/2) fine to medium SAND, well sorted, trace silt, loose, slight fuel odor.	SP	
2.0					Dark gray (N4) silty fine to medium SAND, moist, strong fuel odor and dark staining.	SW	
	X	na	na	160			
4.0					Mottled gray (N6) to yellow-brown (10YR5/4) slightly clayey fine to medium SAND, cohesive to loose, moist, strong fuel odor.	SM	
6.0							
	X	na	na	1100			
8.0					*Soil boring was terminated at 8.1' below ground surface.*		
10.0							
12.0							
14.0							
16.0							
18.0							
20.0							
22.0							
24.0							

Well Diagram



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PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

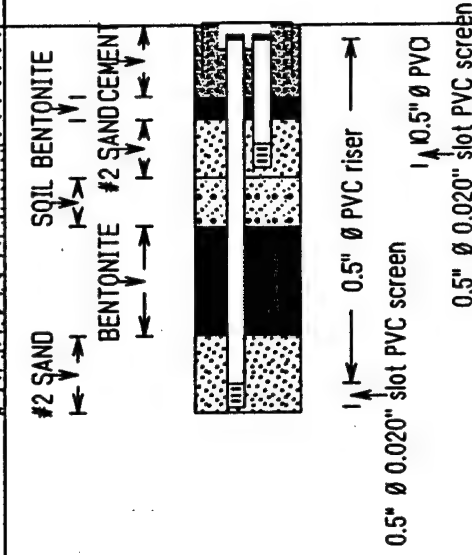
Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HA
Sampling Method (s) HA bucket
Soil Boring Start Date 07/28/94
Soil Boring Termination Date 07/28/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 4
Borehole Depth (feet below surface) 8.1
Deep Casing Installation Date 07/28/94
Deep Seal Grouting Date 07/28/94

Soil Boring Identification Number SH2-MPD
Well Identification Number SH2-MPD
Geol./Eng. Supervising Well Installation S.G. Watkins
Shallow Casing Installation Date 07/28/94
Shallow Seal Grouting Date 07/28/94
Deep Casing Material 0.5" dia. Sch. 80 PVC
Deep Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.5" dia. Sch. 80 PVC
Shallow Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 7.5
D. Screen Interval (feet below surface) 7.5 to 8
S. Casing Interval (feet below surface) 0.3 to 2.5
S. Screen Interval (feet below surface) 2.5 to 3

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Light brown (5YR6/4) fine to medium SAND, well sorted, trace silt, very little fuel odor.	SP	
2.0							
2.5	X	na	na	180	Gray (N5) to pale brown (5YR5/2) silty fine to medium SAND, strong fuel odor and dark staining.	SW	
4.0					Gray (N5) to pale yellow-brown (10YR6/2) clayey fine to medium SAND, cohesive, wet, strong fuel odor.	SM	
6.0							
7.5	X	na	na	850			
8.0					*Soil boring was terminated at 8.1' below ground surface.*		
10.0							
12.0							
14.0							
16.0							
18.0							
20.0							
22.0							
24.0							

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

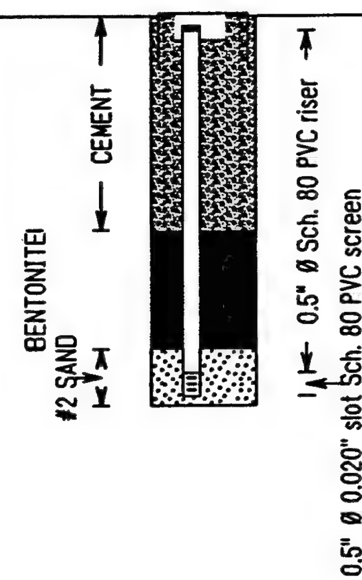
Client AFCEE
Site Shaw AFB, IRP Site FT-01
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HA
Sampling Method (s) HA bucket
Soil Boring Start Date 07/29/94
Soil Boring Termination Date 07/29/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 4

Soil Boring Identification Number SH2-BG1
Well Identification Number SH2-BG1
Geol./Eng. Supervising Well Installation S.G. Watkins
Casing Installation Date 07/29/94
Seal Grouting Date 07/29/94
Casing Material 0.5" dia. Sch. 80 PVC
Screen Material 0.5" dia. 0.020" slot Sch. 80 PVC
Casing Interval (feet below surface) 0.3 to 7.5
Screened Interval (feet below surface) 7.5 to 8
Borehole Depth (feet below surface) 8.2

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class	Graphic Log
0.0					Light brown (5YR5/6) slightly silty fine to medium SAND.	SP	
2.0					Dark yellow-orange (10YR6/6) medium SAND, well sorted, trace silt, loose.	SW	
4.0		na	na	na			
6.0					Very pale gray-orange (10YR7/4) silty fine to medium SAND, loose, moist, no fuel odor. Becoming more silty to clayey with depth.	SM	
8.0					*Soil boring was terminated at 8.2' below ground surface.*		
10.0							
12.0							
14.0							
16.0							
18.0							
20.0							
22.0							
24.0							

Well Diagram



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SITE SS-15

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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

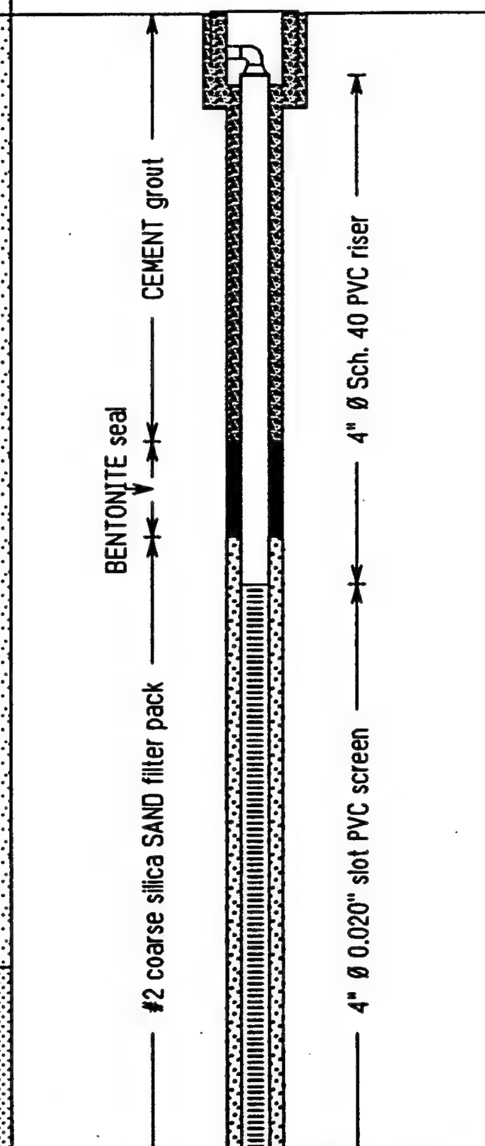
Client: AFCEE
Site: Shaw AFB, IRP Site SS-15
Project Identification Number: 722407-53050
Geol./Eng. Supervising Soil Boring: S.G. Watkins
Drilling Method (s): HSA
Sampling Method (s): 3" SS
Soil Boring Start Date: 07/26/94
Soil Boring Termination Date: 07/26/94
Drilling Company: Alliance Environmental
Borehole Diameter (inches): 10.5
Borehole Depth (feet below surface): 43.5
Surface Elevation (feet MSL): na
Top of Casing Elevation (feet MSL): na

Soil Boring Identification Number: SH1-VW1
Well Identification Number: SH1-VW1
Geol./Eng. Supervising Well Installation: S.G. Watkins
Casing Installation Date: 07/26/94
Seal Grouting Date: 07/27/94
Casing Material: 4" dia. Sch. 40 PVC
Screen Material: 4" dia. 0.020" slot PVC
Casing Interval (feet below surface): 1.3 to 12
Screened Interval (feet below surface): 12 to 41
Total Well Depth (feet below surface): 43.5
Water Level Measurement Date: na
Depth to Water (feet below top of casing): na
Water Level Elevation (feet MSL): na

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
0.0					Brown (5YR4/4) silty SAND (backfill) with asphalt debris.	SM
1.0					Yellow-brown (10YR5/4) to red-brown (10R4/6) silty fine to medium SAND, poorly sorted, moist. Fuel odor.	
9.0–11.0	X	3,5, 5,12	74	620	Dark red-brown (10R3/4) silty fine to medium SAND, dense, moist, fuel odor.	
11.0–13.0	X	2,8, 9,10	66	1600	Dark red-brown (10R3/4) silty fine to medium SAND, less dense, moist, fuel odor.	
13.0–15.0	X	2,10, 11,13	96	1300	Dark red-brown (10R3/4) silty fine to medium SAND, more silt, dense, moist, strong fuel odor.	
15.0–20.0					Very dense material. Color varies from moderate red (5R4/6) to red-brown (10R4/6).	
20.0–22.0	X	9,11, 13,10	138	2500	Yellow-brown (10YR5/4) to green-gray (5GY6/1) slightly silty fine to medium SAND, less dense, moist, fuel odor.	SW

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

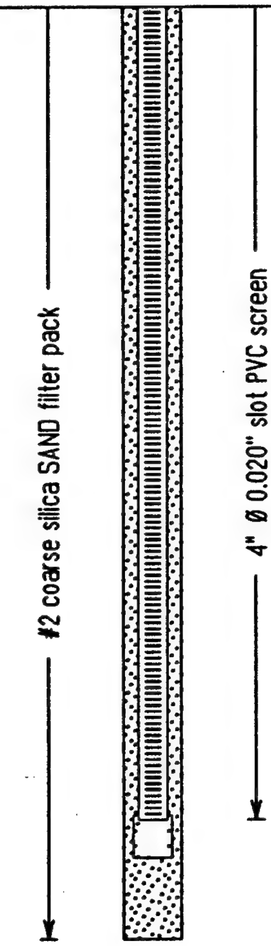
Client AFCEE
Site Shaw AFB, IRP Site SS-15
Project I.D. 722407-53050
Geol./Eng. (S.B.) S.G. Watkins

Well I.D. SH1-VW1
Boring I.D. SH1-VW1
Geol./Eng. (Well) S.G. Watkins

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
24.0						SW
25.0–27.0	X	14,27, 38,41	126	3200	Dark yellow-orange (10YR6/6) fine to medium SAND, very little silt, loose, friable, dry, fuel odor.	
30.0–32.0	X	10,15, 15,12	110	5200	Pale yellow-brown (10YR6/2) to green-gray (5G6/1) fine to medium SAND, trace silt, dense, moist to wet, some fuel odor.	
32.0–34.0	X	10,17, 13,11	136	8400	Pale gray (N5) silty fine to medium SAND grading into dark gray (N3) silty sandy CLAY, plastic, wet, fuel odor.	ML
34.0–38.0					Dark gray (N3) sandy CLAY.	CL
38.0–40.0	X	34,42, 45,50	120	>10000	Pale gray (N7) to pale orange (10YR8/2) slightly silty fine to medium SAND, dense, friable.	SM
					Very pale gray/white (N8) m-c SAND, no silt, loose, moist, no fuel odor.	SP
41.0–43.0	X	29,42, 49,50	106	8600	Pale gray (N7) to yellow-gray (5Y7/2) to light brown (5YR6/4) medium to coarse SAND, well sorted, dense, wet, very strong fuel odor.	
43.5					*Soil boring was terminated at 43.5' below ground surface.*	

Depth scale: 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0, 38.0, 40.0, 42.0, 44.0, 46.0, 48.0, 50.0, 52.0, 54.0

Well Diagram



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PARSONS ENGINEERING SCIENCE

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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

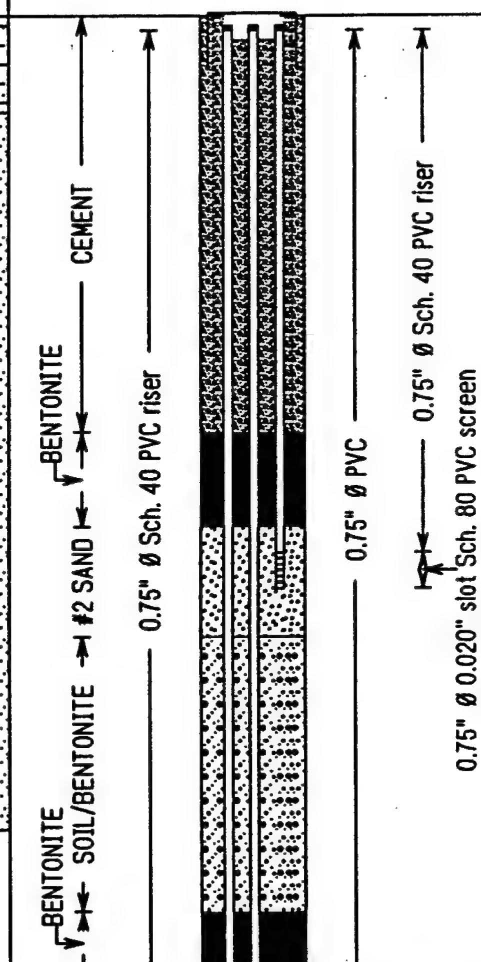
Client AFCEE
Site Shaw AFB, IRP Site SS-15
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HSA
Sampling Method (s) 3" SS
Soil Boring Start Date 07/26/94
Soil Boring Termination Date 07/26/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 8.25
Borehole Depth (feet below surface) 38
Deep Casing Installation Date 07/26/94
Deep Seal Grouting Date 07/26/94
Middle Casing Installation Date 07/26/94
Middle Seal Grouting Date 07/26/94
Shallow Casing Installation Date 07/26/94

Soil Boring Identification Number SH1-MPA
Well Identification Number SH1-MPA
Geol./Eng. Supervising Well Installation S.G. Watkins
Deep Casing Material 0.75" dia. Sch. 40 PVC
Deep Screen Material 0.75" dia. 0.020" slot Sch. 80 PVC
Middle Casing Material 0.75" dia. Sch. 40 PVC
Middle Screen Material 0.75" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.75" dia. Sch. 40 PVC
Shallow Screen Material 0.75" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 37.25
D. Screen Interval (feet below surface) 37.25 to 38
M. Casing Interval (feet below surface) 0.3 to 23.25
M. Screen Interval (feet below surface) 23.25 to 24
S. Casing Interval (feet below surface) 0.3 to 11.25
S. Screen Interval (feet below surface) 11.25 to 12
Shallow Seal Grouting Date 07/27/94

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
0.0					Red-brown (10R4/6) sandy SILT.	ML
2.0					Dark brown-red (10R3/4) clayey to silty fine to medium SAND, cohesive, dry.	SM
4.0						
6.0					Red (5R4/6) to red-brown (10R3/4) in color, moist to wet, fuel odor.	
8.0						
10.0	X	7,7, 11,12	46	1200	Dark red-brown (10R3/4) to red (5R4/6) silty to clayey SAND, poorly sorted, moist to wet, fuel odor.	
12.0						
14.0						
16.0	X	5,5, 7,10	72	1800	Same as 10'-12' sample. Fuel odor.	
18.0						
20.0						SW

Well Diagram



GTGS \ 722407 \ SH1-MPA.LOG

PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client AFCEE
Site Shaw AFB, IRP Site SS-15
Project I.D. 722407-53050
Geol./Eng. (S.B.) S.G. Watkins

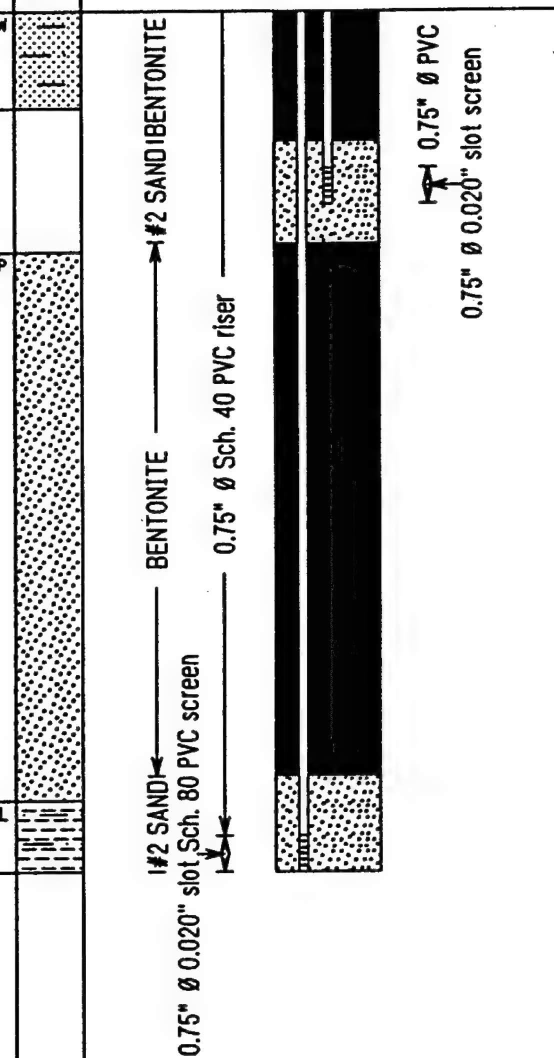
Well I.D. SH1-MPA
Boring I.D. SH1-MPA
Geol./Eng. (Well) S.G. Watkins

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
20.0–22.0	X	6,12, 13,15	106	1900	Light brown (5YR5/6) slightly silty fine to medium SAND, moderately dense, friable, moist, fuel odor.	SW
25.0–27.0	X	13,15, 17,28	120	8200	Yellow-brown (10YR5/4) to pale brown (5YR5/6) fine to medium SAND, well sorted, trace silt, dense, dry to moist, slight fuel odor.	SP
30.0–32.0	X	11,18, 19,15	118	1800	Pale gray (N7) to pale gray-orange (10YR7/4) fine to medium SAND, well sorted, some silt, dense, friable, slight fuel odor.	
36.0–38.0	X	20,22, 35,36	112	>10000	Pale gray (N7) to pale yellow-orange (10YR8/6) mottled m-c SAND, well sorted, tr silt, dense, moist, V strg fuel odor.	
37.5–38.0					Dark gray (N3) silty CLAY.	CL
					Soil boring was terminated at 38' below ground surface.	

Depth scale: 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0, 38.0, 40.0, 42.0, 44.0, 46.0, 48.0, 50.0

Graphic Log

Well Diagram



PARSONS ENGINEERING SCIENCE

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GTGS \ 722407 \ SH1-MPA.LOG

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client: AFCEE
Site: Shaw AFB, IRP Site SS-15
Project Identification Number: 722407-53050
Geol./Eng. Supervising Soil Boring: S.G. Watkins
Drilling Method (s): HSA
Sampling Method (s): 3" SS
Soil Boring Start Date: 07/27/94
Soil Boring Termination Date: 07/27/94
Drilling Company: Alliance Environmental
Borehole Diameter (inches): 8.25
Borehole Depth (feet below surface): 38.3
Deep Casing Installation Date: 07/27/94
Deep Seal Grouting Date: 07/27/94
Middle Casing Installation Date: 07/27/94
Middle Seal Grouting Date: 07/27/94
Shallow Casing Installation Date: 07/27/94

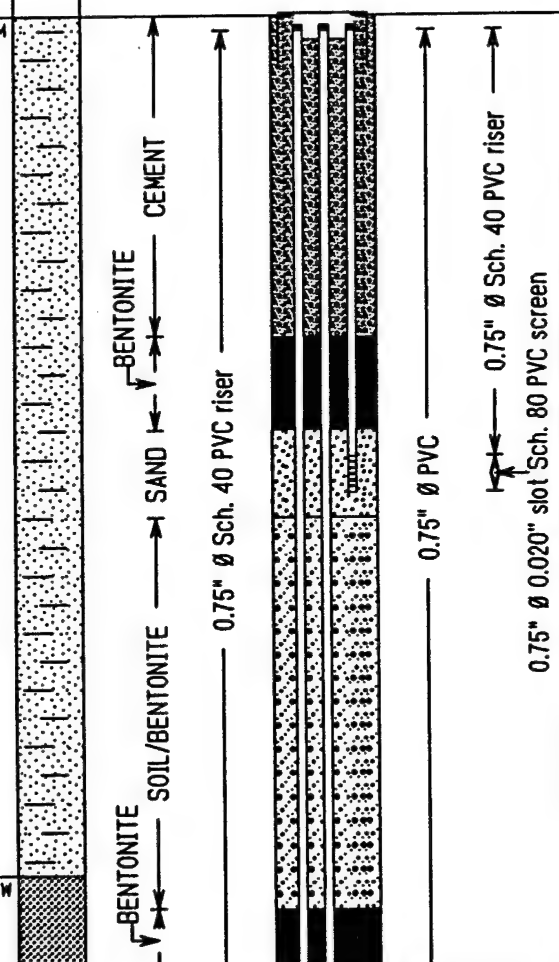
Soil Boring Identification Number: SH1-MPB
Well Identification Number: SH1-MPB
Geol./Eng. Supervising Well Installation: S.G. Watkins
Deep Casing Material: 0.75" dia. Sch. 40 PVC
Deep Screen Material: 0.75" dia. 0.020" slot Sch. 80 PVC
Middle Casing Material: 0.75" dia. Sch. 40 PVC
Middle Screen Material: 0.75" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material: 0.75" dia. Sch. 40 PVC
Shallow Screen Material: 0.75" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface): 0.3 to 37.25
D. Screen Interval (feet below surface): 37.25 to 38
M. Casing Interval (feet below surface): 0.3 to 23.25
M. Screen Interval (feet below surface): 23.25 to 24
S. Casing Interval (feet below surface): 0.3 to 9.25
S. Screen Interval (feet below surface): 9.25 to 10
Shallow Seal Grouting Date: 07/28/94

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
0.0					Red (5R4/6) to dark red-brown (10R3/4) silty fine to medium SAND, poorly sorted, dense, friable, dry to moist. Some color changes to red-orange (10R6/6).	SM
2.0						
4.0						
6.0					Fuel odor.	
8.0	X	3,7, 8,12	na	57	Dark red-brown (10R3/4) very silty fine to medium SAND, poorly sorted, dense, moist, strong fuel odor and staining.	
10.0	X	10,6, 12,18	na	410	Moderate red (5R4/6) silty fine SAND, poorly sorted, moderately dense, friable, moderate fuel odor.	
12.0						
14.0						
16.0						
18.0	X	11,12, 4,15	na	78	Moderate red-orange (10R6/6) fine to medium SAND, well sorted, trace silt, dense, friable, dry to moist, very little fuel odor.	SW
20.0						

Graphic Log

Well Diagram



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client: AFCEE
Site: Shaw AFB, IRP Site SS-15
Project I.D.: 722407-53050
Geol./Eng. (S.B.): S.G. Watkins

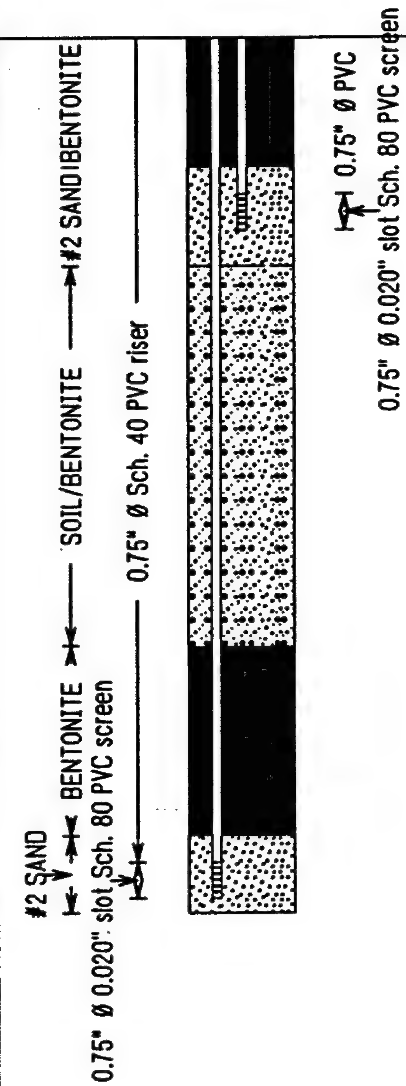
Well I.D.: SH1-MPB
Boring I.D.: SH1-MPB
Geol./Eng. (Well): S.G. Watkins

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
20.0						SW
22.0–24.0	X	8,12, 4,15	na	57	Pale yellow-brown (10YR6/2) to pale gray-orange (10YR7/4) silty fine to medium SAND, loose, moist, slight fuel odor.	SM
26.0						SP
28.0–30.0	X	19,30, 27,28	na	42	Pale gray (N7) to brown-gray (5YR4/1) and yellow-gray (5Y7/2) fine to medium SAND, well sorted, trace silt, dense, moist, very little fuel odor.	
34.0–36.0	X	6,15, 24,30	na	2000	Mottled dark gray (N3)/brown (5YR3/4)/red (5R3/4) silty CLAY, very dense, cohesive, very tight, moist to wet, very strong fuel odor.	CL
36.0–38.0	X	16,23, 24,36	na	6800	Pale gray (N7) to dk yellw-orng (10YR6/6) silty f-m SAND, dense, friable, moist, strg fuel odor. Mottled to streaked at 37'. Increase coarseness & less silt w/ depth.	SM
38.0					Pale gray (N7) to very pale orange (10YR8/2) m-c SAND, well sorted, dense.	SP

Soil boring was terminated at 38.3' below ground surface.

Depth scale: 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0, 38.0, 40.0, 42.0, 44.0, 46.0, 48.0, 50.0

Well Diagram



PARSONS ENGINEERING SCIENCE

GTGS \ 722407 \ SH1-MPB.LOG

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client AFCEE
Site Shaw AFB, IRP Site SS-15
Project Identification Number 722407-53050
Geol./Eng. Supervising Soil Boring S.G. Watkins
Drilling Method (s) HSA
Sampling Method (s) 3" SS
Soil Boring Start Date 07/27/94
Soil Boring Termination Date 07/27/94
Drilling Company Alliance Environmental
Borehole Diameter (inches) 8.25
Borehole Depth (feet below surface) 40
Deep Casing Installation Date 07/27/94
Deep Seal Grouting Date 07/27/94

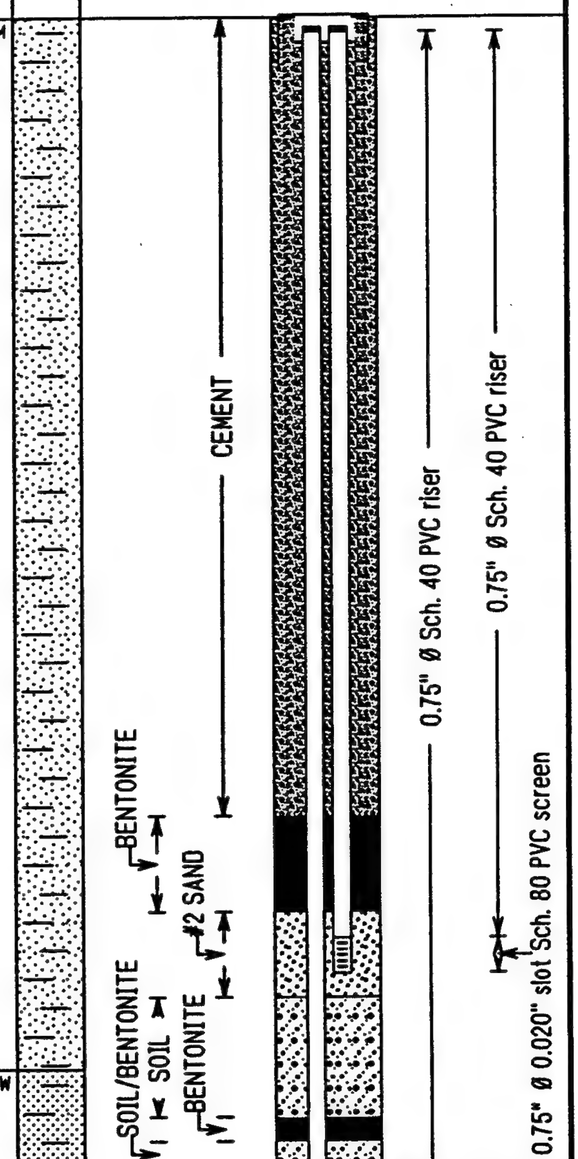
Soil Boring Identification Number SH1-MPC
Well Identification Number SH1-MPC
Geol./Eng. Supervising Well Installation S.G. Watkins
Shallow Casing Installation Date 07/27/94
Shallow Seal Grouting Date 07/27/94
Deep Casing Material 0.75" dia. Sch. 40 PVC
Deep Screen Material 0.75" dia. 0.020" slot Sch. 80 PVC
Shallow Casing Material 0.75" dia. Sch. 40 PVC
Shallow Screen Material 0.75" dia. 0.020" slot Sch. 80 PVC
D. Casing Interval (feet below surface) 0.3 to 37.25
D. Screen Interval (feet below surface) 37.25 to 38
S. Casing Interval (feet below surface) 0.3 to 19.25
S. Screen Interval (feet below surface) 19.25 to 20

Comments:

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
0.0					Dark red-brown (10R3/4) to moderate red (5R4/6) silty fine to medium SAND, poorly sorted, dense, dry to moist, no fuel odor.	SM
2.0						
4.0						
6.0						
8.0						
				4		
10.0						
12.0						
14.0						
16.0						
18.0						
20.0						
				0		
22.0					Pale yellow-brown (10YR6/2) to light brown (5YR5/6) slightly silty f-m SAND, loose, dry to moist, no fuel odor.	SW
24.0						

Graphic Log

Well Diagram



PARSONS ENGINEERING SCIENCE

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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

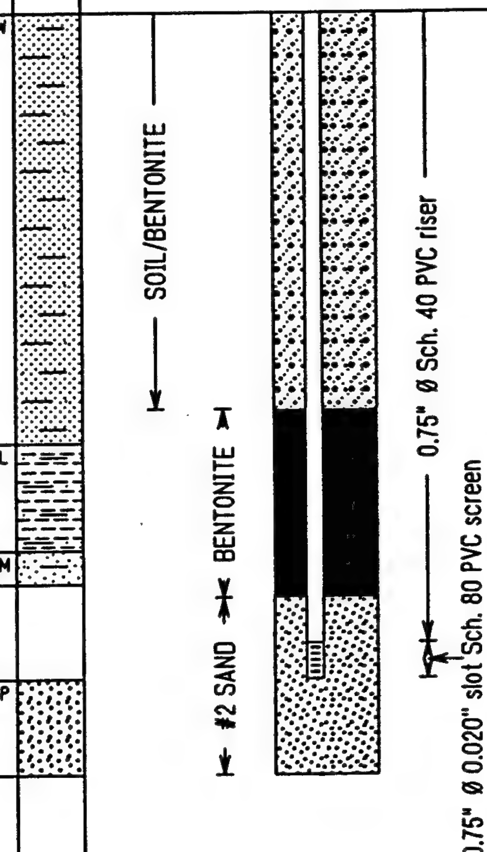
Client AFCEE
Site Shaw AFB, IRP Site SS-15
Project I.D. 722407-53050
Geol./Eng. (S.B.) S.G. Watkins

Well I.D. SH1-MPC
Boring I.D. SH1-MPC
Geol./Eng. (Well) S.G. Watkins

DEPTH (feet)	Sample	Blows/6 in.	Soil PID (ppm)	Soil TVHC (ppm)	Lithologic Description	Soil Class
24.0						SW
33.0					Dark gray (N3) to dark brown-black (5YR2/1) silty CLAY, slight fuel odor.	CL
34.0–36.0	X	12,26, 42,50	na	5800	Mottled dark gray (N3) to red-brown (10R2/2) silty CLAY, very dense, cohesive, moist, strong fuel odor.	
35.5–36.0					Dark yellow-orange (10YR6/6) silty medium to coarse SAND, 20% silt, dense, friable, moist, strong fuel odor.	SM
38.0–40.0	X	30 >50	na	>10000	Dk yellow-orange (10YR6/6) to yellow-brown (10YR5/4) m-c SAND, well sorted, tr silt, dense, friable, moist, V strg fuel odor.	SP
40.0					Yellow slightly silty m-c SAND.	
					Soil boring was terminated at 40' below ground surface.	

Depth scale: 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0, 38.0, 40.0, 42.0, 44.0, 46.0, 48.0, 50.0, 52.0, 54.0

Graphic Log / Well Diagram



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PARSONS ENGINEERING SCIENCE

APPENDIX B

OXYGEN UTILIZATION DATA PLOTS
SITE FT-01

Initial Respiration Test

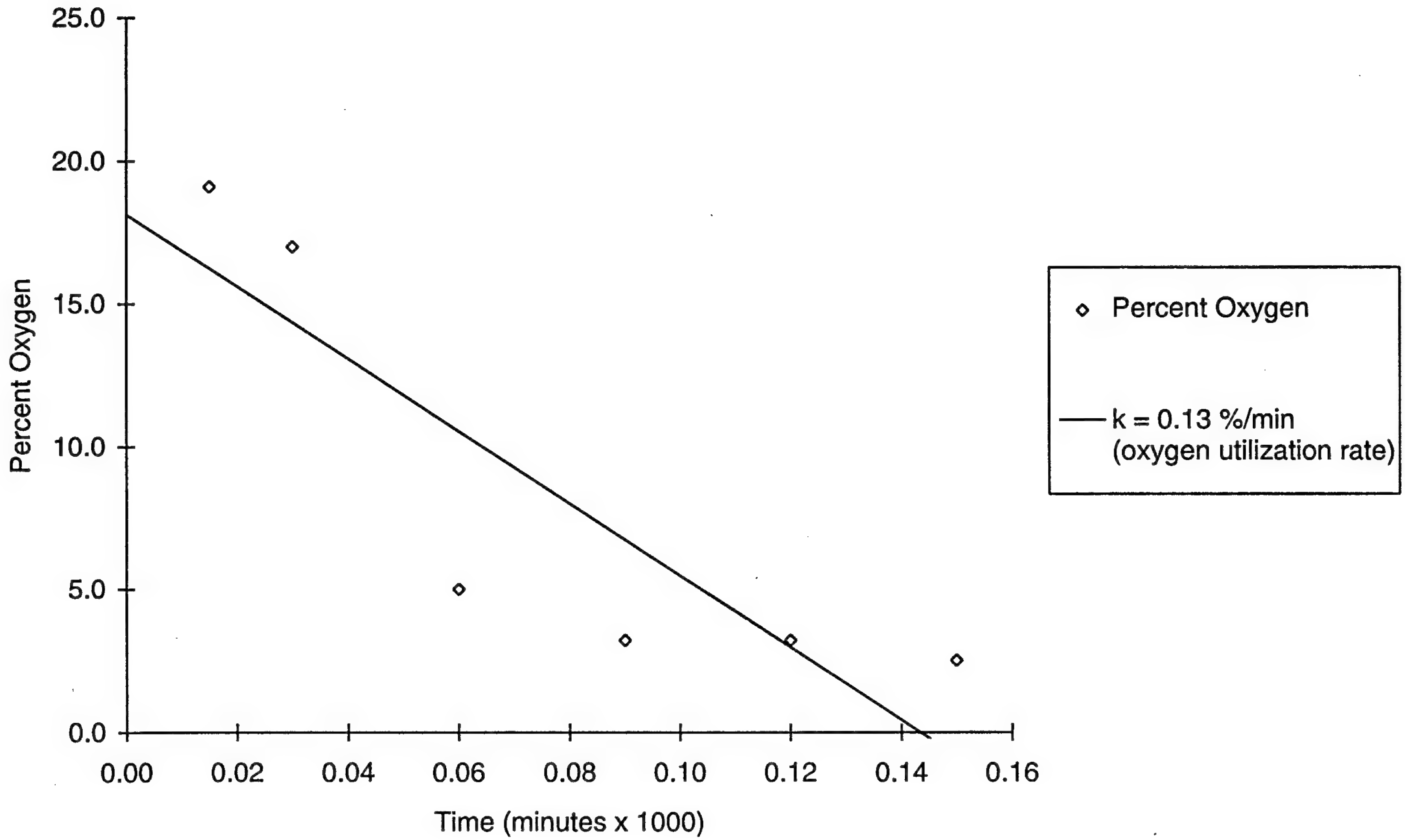
Site FT-01 (Fire Training Area #1)

Shaw AFB, SC

Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2	Total Hydro-carbon	Helium	Comments	New x-values	Trend of O2/ Time	k
SH2-VW1	10/04/94	0.00	11:45	0.01	0.01	0.01	19.1	2.2	260	--		0	18.13726	0.126502
SH2-VW1	10/04/94	0.00	12:00	0.02	0.02	0.03	17.0	3.5	1,400	1.5		0.15	-0.838082	
SH2-VW1	10/04/94	0.00	12:30	0.04	0.04	0.06	5.0	9.5	>10,000	--				
SH2-VW1	10/04/94	0.00	13:00	0.06	0.06	0.09	3.2	9.5	>10,000	--				
SH2-VW1	10/04/94	0.00	13:30	0.08	0.08	0.12	3.2	9.5	>10,000	--				
SH2-VW1	10/04/94	0.00	14:00	0.10	0.10	0.15	2.5	9.5	>10,000	--				
SH2-MPA-4.5	10/04/94	0.00	11:30	0.00	0.00	0.00	21.0	0.5	28	--		0	19.758883	0.013107
SH2-MPA-4.5	10/04/94	0.00	12:00	0.02	0.02	0.03	20.2	0.6	44	1.4		1.62	-1.473847	
SH2-MPA-4.5	10/04/94	0.00	12:30	0.04	0.04	0.06	19.5	0.5	48	--				
SH2-MPA-4.5	10/04/94	0.00	13:00	0.06	0.06	0.09	19.2	0.7	50	--				
SH2-MPA-4.5	10/04/94	0.00	13:30	0.08	0.08	0.12	19.0	0.8	59	--				
SH2-MPA-4.5	10/04/94	0.00	14:00	0.10	0.10	0.15	17.7	0.8	58	--				
SH2-MPA-4.5	10/04/94	0.00	16:18	0.20	0.20	0.29	14.9	1.8	47	--				
SH2-MPA-4.5	10/04/94	0.00	19:20	0.33	0.33	0.47	11.5	1.8	880	1.4				
SH2-MPA-4.5	10/04/94	0.00	23:30	0.50	0.50	0.72	8.0	3.7	1,500	--				
SH2-MPA-4.5	10/05/94	1.00	08:45	-0.11	0.89	1.28	2.3	5.5	100	1.1				
SH2-MPA-4.5	10/05/94	1.00	14:25	0.12	1.12	1.62	0.9	5.8	160	0.95				
SH2-MPA-8	10/04/94	0.00	11:34	0.00	0.00	0.00	21.0	0.5	52	--	Soil Temp = 72.2 deg. F	0	15.341955	0.004510
SH2-MPA-8	10/04/94	0.00	12:00	0.02	0.02	0.03	19.3	0.7	160	1.2	Temp = 73.7 deg. F	1.62	8.035502	
SH2-MPA-8	10/04/94	0.00	12:30	0.04	0.04	0.06	15.5	0.65	360	--	Temp = 74.4 deg. F			
SH2-MPA-8	10/04/94	0.00	13:00	0.06	0.06	0.09	13.1	0.7	500	--	Temp = 71.9 deg. F			
SH2-MPA-8	10/04/94	0.00	13:30	0.08	0.08	0.12	12.4	0.8	570	--				
SH2-MPA-8	10/04/94	0.00	14:00	0.10	0.10	0.15	10.5	0.8	640	--	Temp = 73.8 deg. F			
SH2-MPA-8	10/04/94	0.00	16:21	0.20	0.20	0.29	12.5	0.8	800	--	Temp = 73.7 deg. F			
SH2-MPA-8	10/04/94	0.00	19:20	0.33	0.33	0.47	12.5	0.7	3,000	1.2	Temp = 74.0 deg. F			
SH2-MPA-8	10/04/94	0.00	23:30	0.50	0.50	0.72	11.1	1.0	1,200	--	Temp = 74.2 deg. F			
SH2-MPA-8	10/05/94	1.00	08:45	-0.11	0.89	1.28	9.4	1.1	1,600	0.93	Temp = 74.5 deg. F			
SH2-MPA-8	10/05/94	1.00	14:25	0.12	1.12	1.62	9.7	0.8	1,200	0.65	Temp = 73.8 deg. F			
SH2-MPA-8	10/06/94	2.00	09:40	-0.08	1.92	2.77	--	--	1800	0.15				
SH2-MPB-4	10/04/94	0.00	11:30	0.00	0.00	0.00	20.3	0.2	18	--	Soil Temp = 64.5 deg. F	0	21.344588	0.006902
SH2-MPB-4	10/04/94	0.00	12:00	0.02	0.02	0.03	20.5	0.25	19	2.5	Temp = 67.8 deg. F	2.75	2.3635159	
SH2-MPB-4	10/04/94	0.00	12:30	0.04	0.04	0.06	20.3	0.3	84	2.5				
SH2-MPB-4	10/04/94	0.00	13:00	0.06	0.06	0.09	20.3	0.3	50	2.3	Temp = 68 deg. F			
SH2-MPB-4	10/04/94	0.00	14:00	0.10	0.10	0.15	20.1	0.3	56	--	Temp = 70.5 deg. F			
SH2-MPB-4	10/04/94	0.00	16:15	0.20	0.20	0.29	19.5	0.6	50	--	Temp = 71.1 deg. F			
SH2-MPB-4	10/04/94	0.00	19:30	0.33	0.33	0.48	18.5	0.75	52	2.3	Temp = 71.8 deg. F			
SH2-MPB-4	10/04/94	0.00	23:30	0.50	0.50	0.72	18.0	0.75	--	--	Temp = 72.2 deg. F			
SH2-MPB-4	10/05/94	1.00	08:45	-0.11	0.89	1.28	13.9	1.5	94	2.3	Temp = 72.6 deg. F			
SH2-MPB-4	10/05/94	1.00	14:35	0.13	1.13	1.63	11.3	2.1	100	1.7	Temp = 72.1 deg. F			
SH2-MPB-4	10/06/94	2.00	09:15	-0.09	1.91	2.75	0.6	5.7	140	2.0	Temp = 72.3 deg. F			

SH2-MPB-8	10/04/94	0.00	11:35	0.00	0.00	0.00	20.8	0.25	24	–	Soil Temp = 70.1 deg. F	0	16.413488	0.005139
SH2-MPB-8	10/04/94	0.00	12:05	0.02	0.02	0.04	19.0	0.75	76	1.2	Temp = 72.3 deg. F	2.75	2.2802728	
SH2-MPB-8	10/04/94	0.00	12:35	0.05	0.05	0.07	17.2	0.75	190	1.3				
SH2-MPB-8	10/04/94	0.00	13:05	0.07	0.07	0.10	16.0	0.8	220	1.2	Temp = 71.1 deg. F			
SH2-MPB-8	10/04/94	0.00	13:35	0.09	0.09	0.13	15.3	0.8	260	–				
SH2-MPB-8	10/04/94	0.00	14:05	0.11	0.11	0.16	15.1	0.8	320	–	Temp = 73.1 deg. F			
SH2-MPB-8	10/04/94	0.00	16:15	0.20	0.20	0.29	13.0	0.9	360	–	Temp = 73.0 deg. F			
SH2-MPB-8	10/04/94	0.00	19:30	0.33	0.33	0.48	10.8	0.9	490	1.4	Temp = 73.6 deg. F			
SH2-MPB-8	10/04/94	0.00	23:30	0.50	0.50	0.72	11.9	1.0	–	–	Temp = 73.9 deg. F; O2 reading may be in error?			
SH2-MPB-8	10/05/94	1.00	08:50	-0.11	0.89	1.28	7.0	1.1	800	1.5	Temp = 74.3 deg. F			
SH2-MPB-8	10/05/94	1.00	14:40	0.13	1.13	1.63	5.8	1.5	4,000	1.1	Temp = 73.7 deg. F			
SH2-MPB-8	10/06/94	2.00	09:15	-0.09	1.91	2.75	5.9	1.5	2200	1.1	Temp = 74 deg. F			
SH2-MPC-3	10/04/94	0.00	11:35	0.00	0.00	0.00	20.5	0.25	29	–		0	20.243525	0.004455
SH2-MPC-3	10/04/94	0.00	12:05	0.02	0.02	0.04	20.1	0.3	44	2.7		2.75	7.9924751	
SH2-MPC-3	10/04/94	0.00	12:35	0.05	0.05	0.07	20.0	0.3	70	2.7				
SH2-MPC-3	10/04/94	0.00	13:05	0.07	0.07	0.10	19.9	0.4	54	2.3				
SH2-MPC-3	10/04/94	0.00	14:05	0.11	0.11	0.16	19.1	0.4	62	–				
SH2-MPC-3	10/04/94	0.00	16:10	0.19	0.19	0.28	18.5	0.6	62	–				
SH2-MPC-3	10/04/94	0.00	19:35	0.34	0.34	0.49	18.0	0.6	100	2.6				
SH2-MPC-3	10/04/94	0.00	23:30	0.50	0.50	0.72	17.8	0.75	–	–				
SH2-MPC-3	10/05/94	1.00	09:00	-0.10	0.90	1.29	14.4	1.0	110	2.7				
SH2-MPC-3	10/05/94	1.00	14:45	0.14	1.14	1.64	13.0	1.3	130	2.1				
SH2-MPC-3	10/06/94	2.00	09:20	-0.09	1.91	2.75	7.9	2.9	180	2.6				
SH2-MPD-3	10/04/94	0.00	11:40	0.01	0.01	0.01	21.0	0.5	64	–	Soil Temp = 65.9 deg. F	0	20.278784	0.012586
SH2-MPD-3	10/04/94	0.00	12:00	0.02	0.02	0.03	20.1	0.5	66	2.7	Temp = 69.3 deg. F	1.64	-0.361806	
SH2-MPD-3	10/04/94	0.00	12:30	0.04	0.04	0.06	19.3	0.5	50	–	Temp = 71.6 deg. F			
SH2-MPD-3	10/04/94	0.00	13:00	0.06	0.06	0.09	19.1	0.6	64	–	Temp = 69.3 deg. F			
SH2-MPD-3	10/04/94	0.00	13:30	0.08	0.08	0.12	18.9	0.6	86	–				
SH2-MPD-3	10/04/94	0.00	14:00	0.10	0.10	0.15	17.5	0.6	88	–	Temp = 71.2 deg. F			
SH2-MPD-3	10/04/94	0.00	16:25	0.20	0.20	0.30	16.0	0.75	50	–	Temp = 71.7 deg. F; switch meters			
SH2-MPD-3	10/04/94	0.00	19:20	0.33	0.33	0.47	14.5	0.75	200	2.9	Temp = 72 deg. F			
SH2-MPD-3	10/04/94	0.00	23:30	0.50	0.50	0.72	12.0	1.25	–	–	Temp = 72.2 deg. F			
SH2-MPD-3	10/05/94	1.00	08:45	-0.11	0.89	1.28	3.5	3.0	110	3.1	Temp = 72.5 deg. F			
SH2-MPD-3	10/05/94	1.00	14:50	0.14	1.14	1.64	0.0	3.8	79	2.4	Temp = 71.9 deg. F			
SH2-MPD-3	10/06/94	2.00	09:20	-0.09	1.91	2.75	0.0	4.3	140	2.6	Temp = 72 deg. F			

Respiration Test
Site FT-01 - SH2-VW1
Shaw AFB, SC



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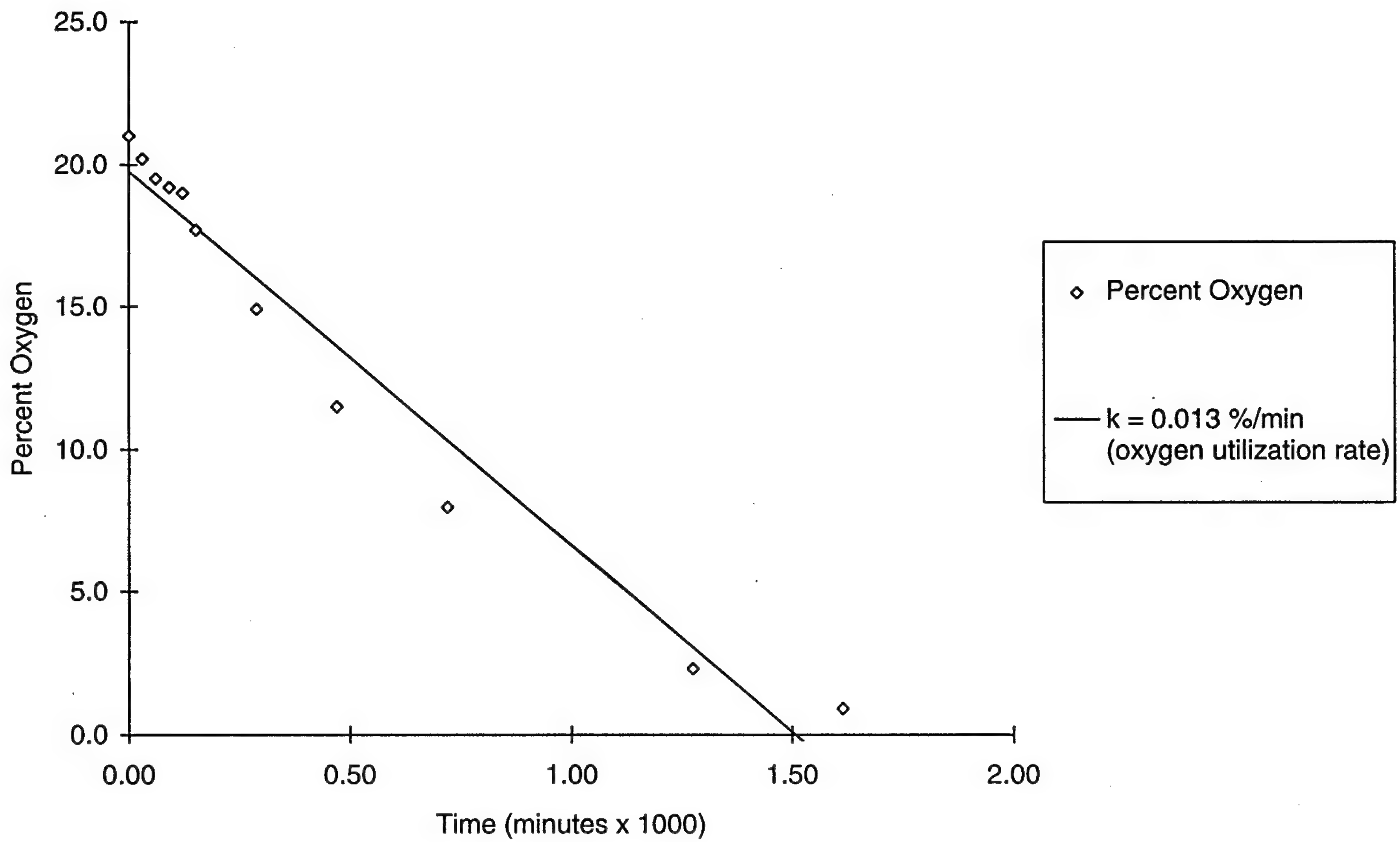
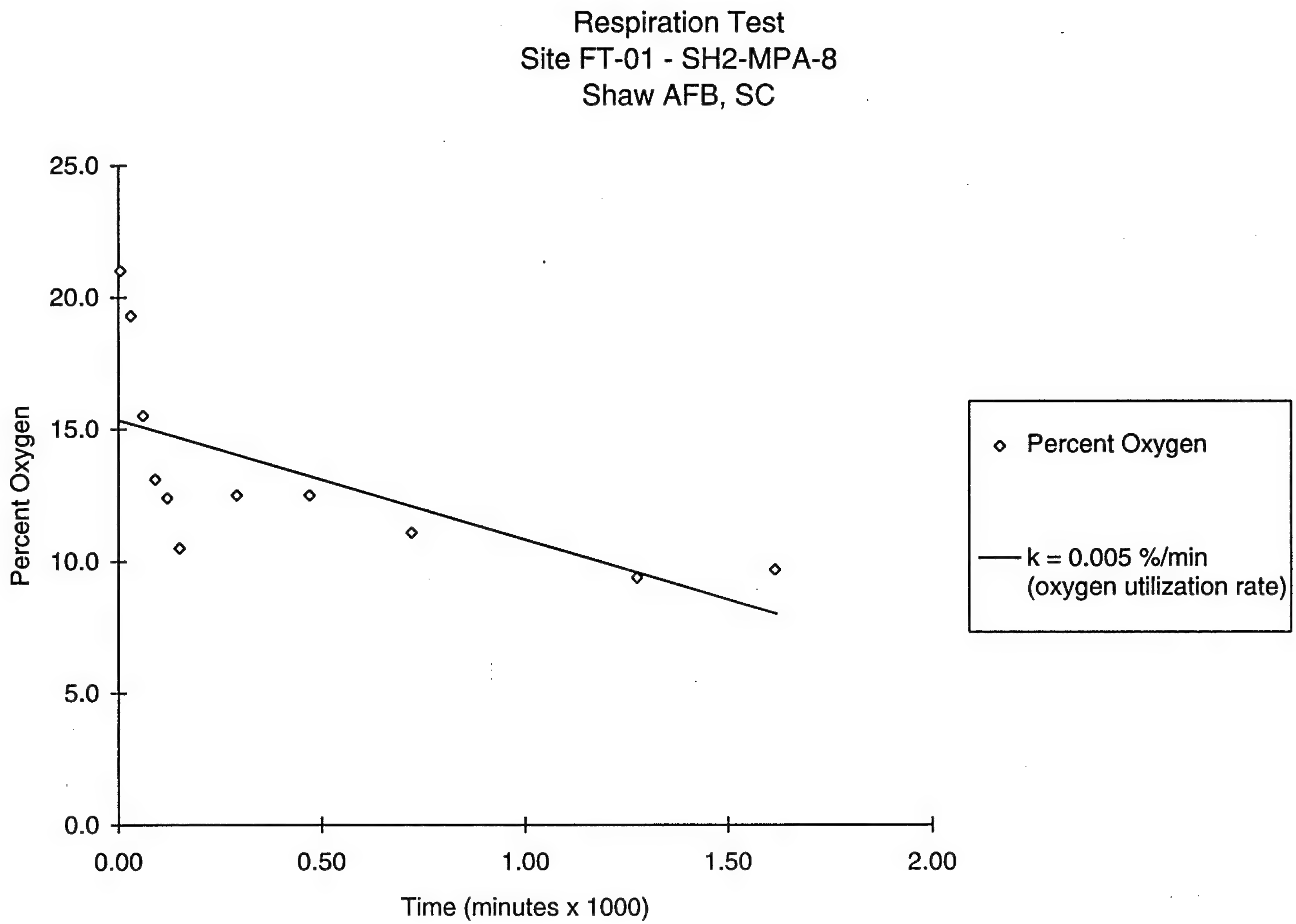
11/4/94 10:48 AM

Respiration Test
Site FT-01 - SH2-MPA-4.5
Shaw AFB, SC





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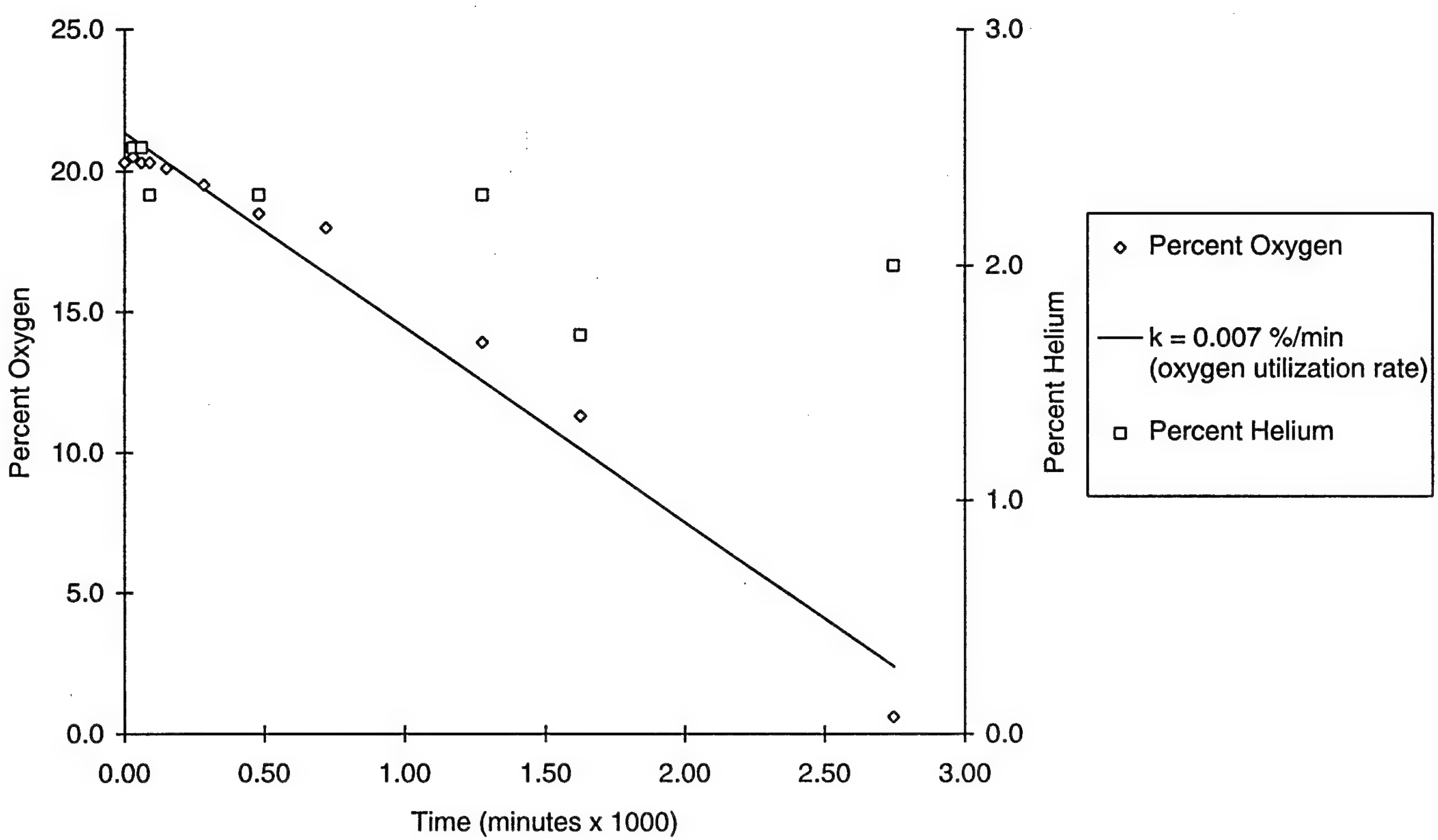
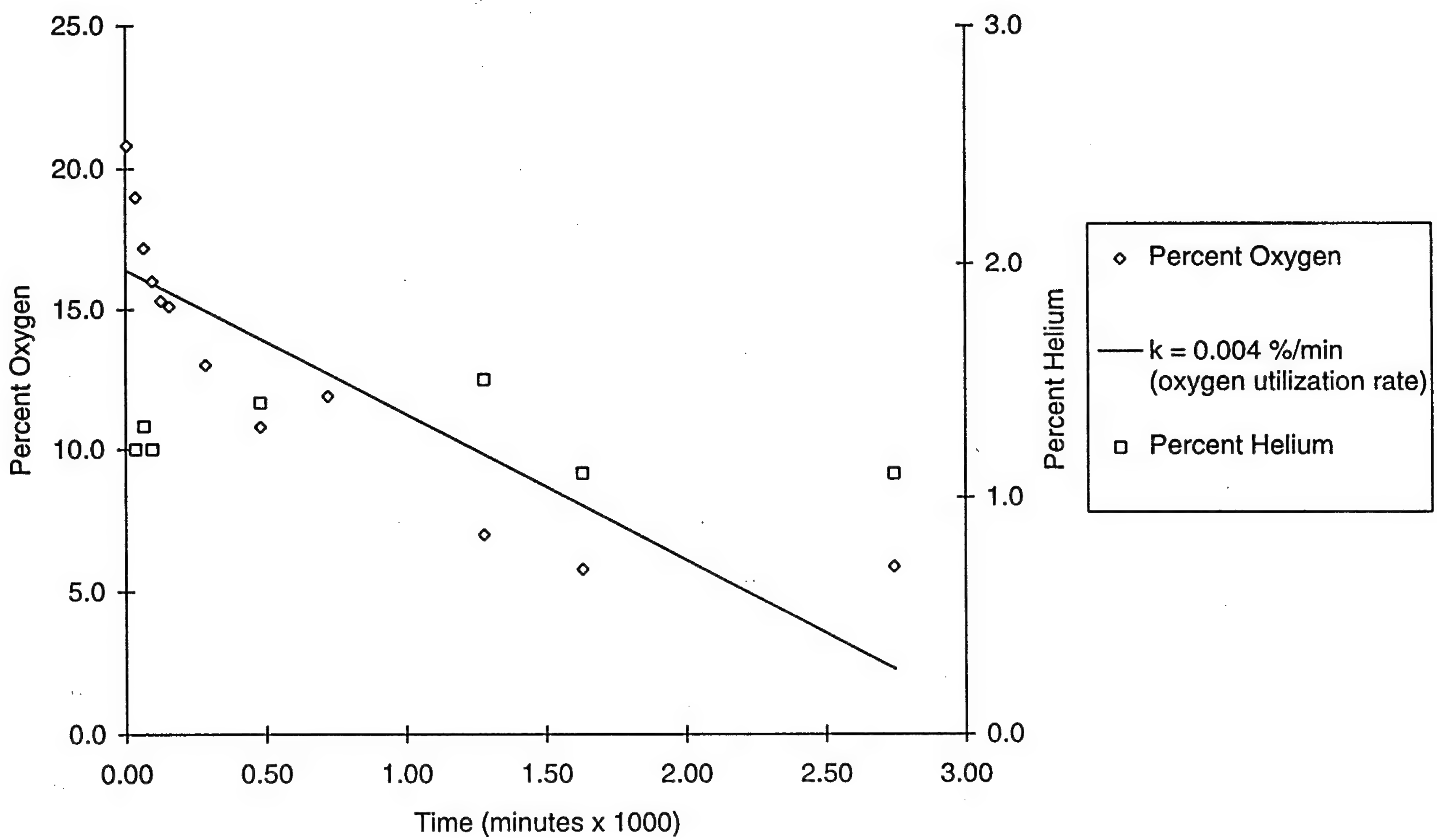
11/4/94 10:48 AM

Respiration Test
Site FT-01 - SH2-MPB-4
Shaw AFB, SC



Respiration Test
Site FT-01 - SH2-MPB-8
Shaw AFB, SC



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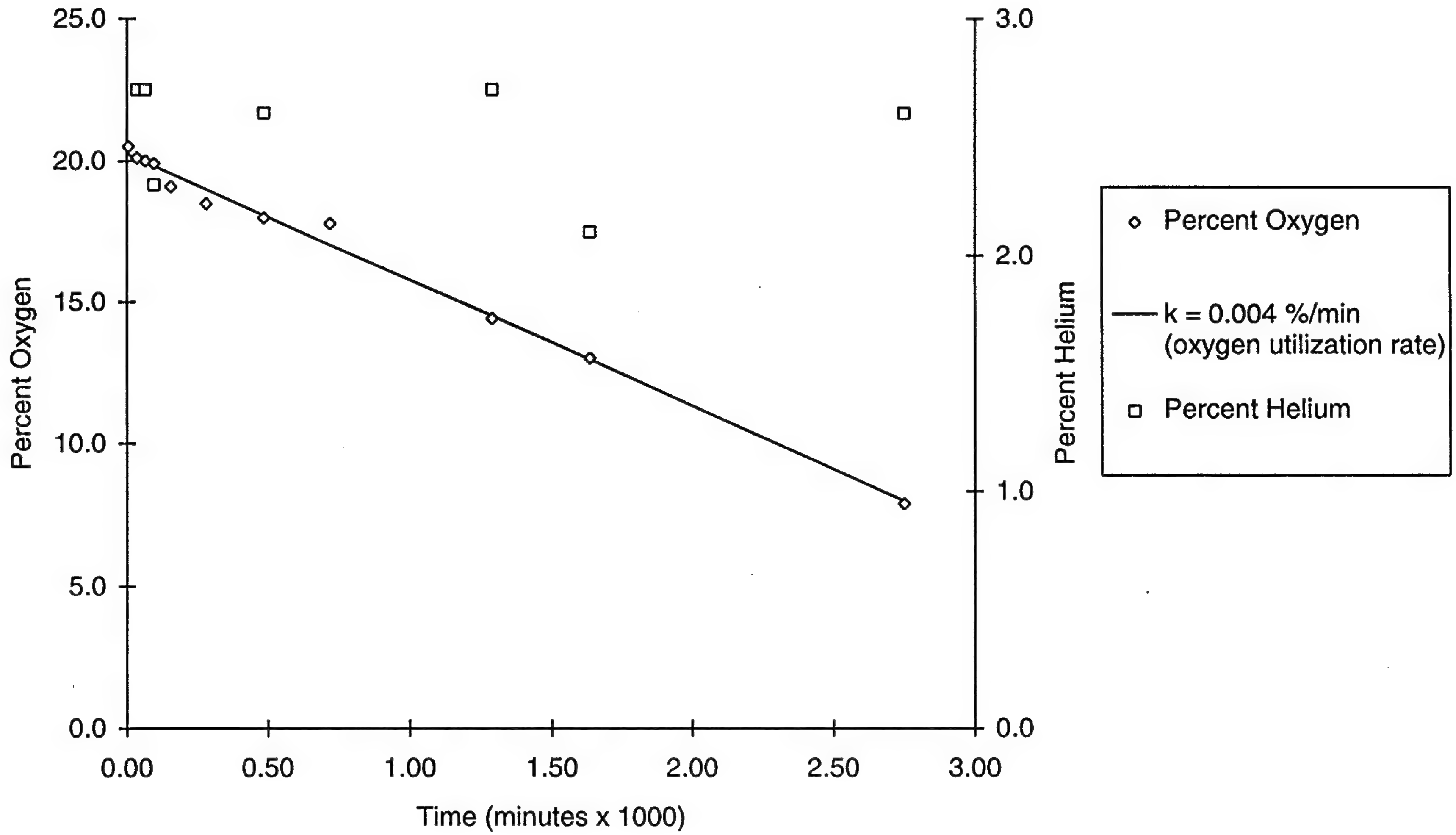
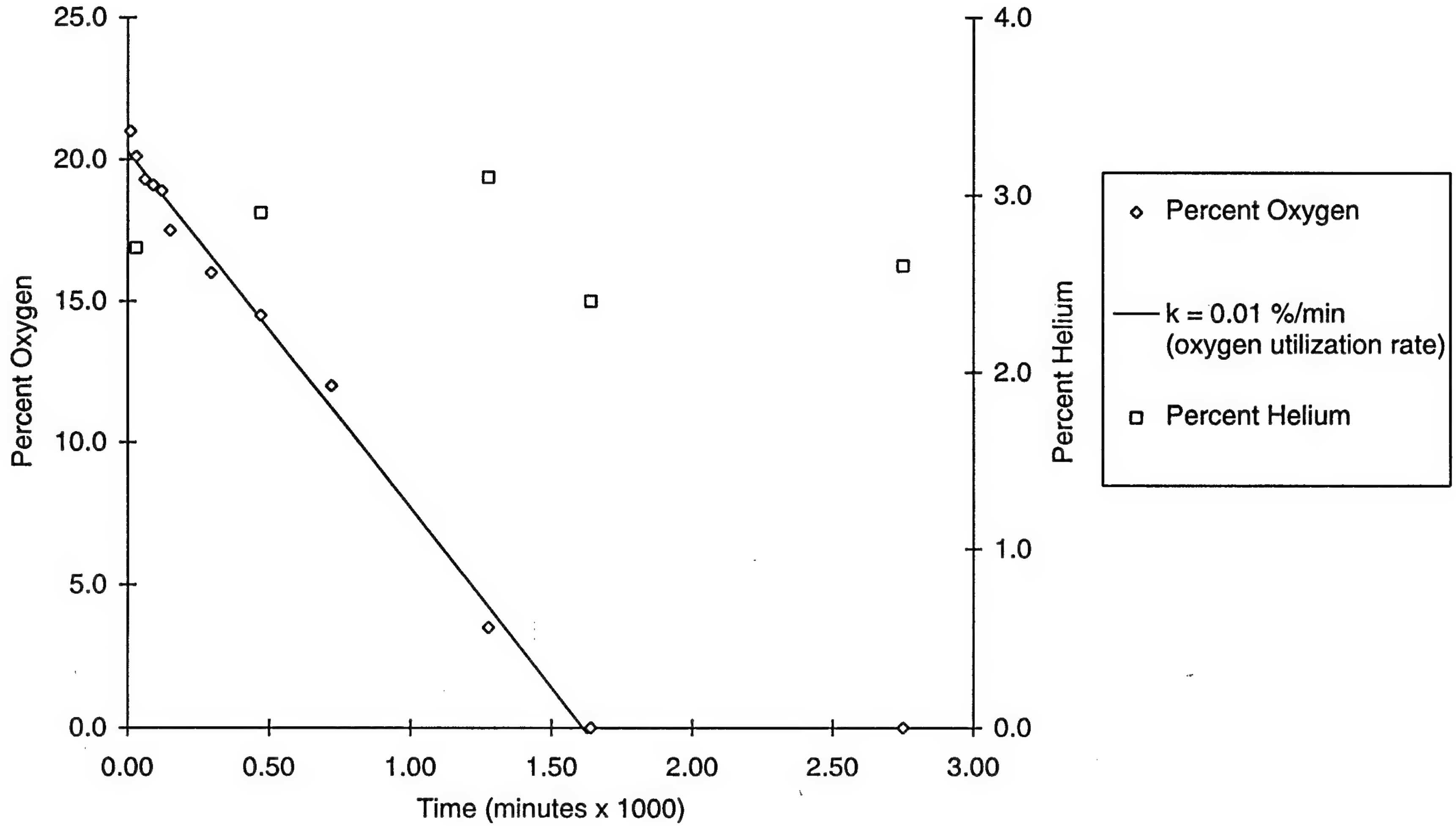
Respiration Test
Site FT-01 - SH2-MPC-3
Shaw AFB, SC



Respiration Test
Site FT-01 - SH2-MPD-3
Shaw AFB, SC



APPENDIX C

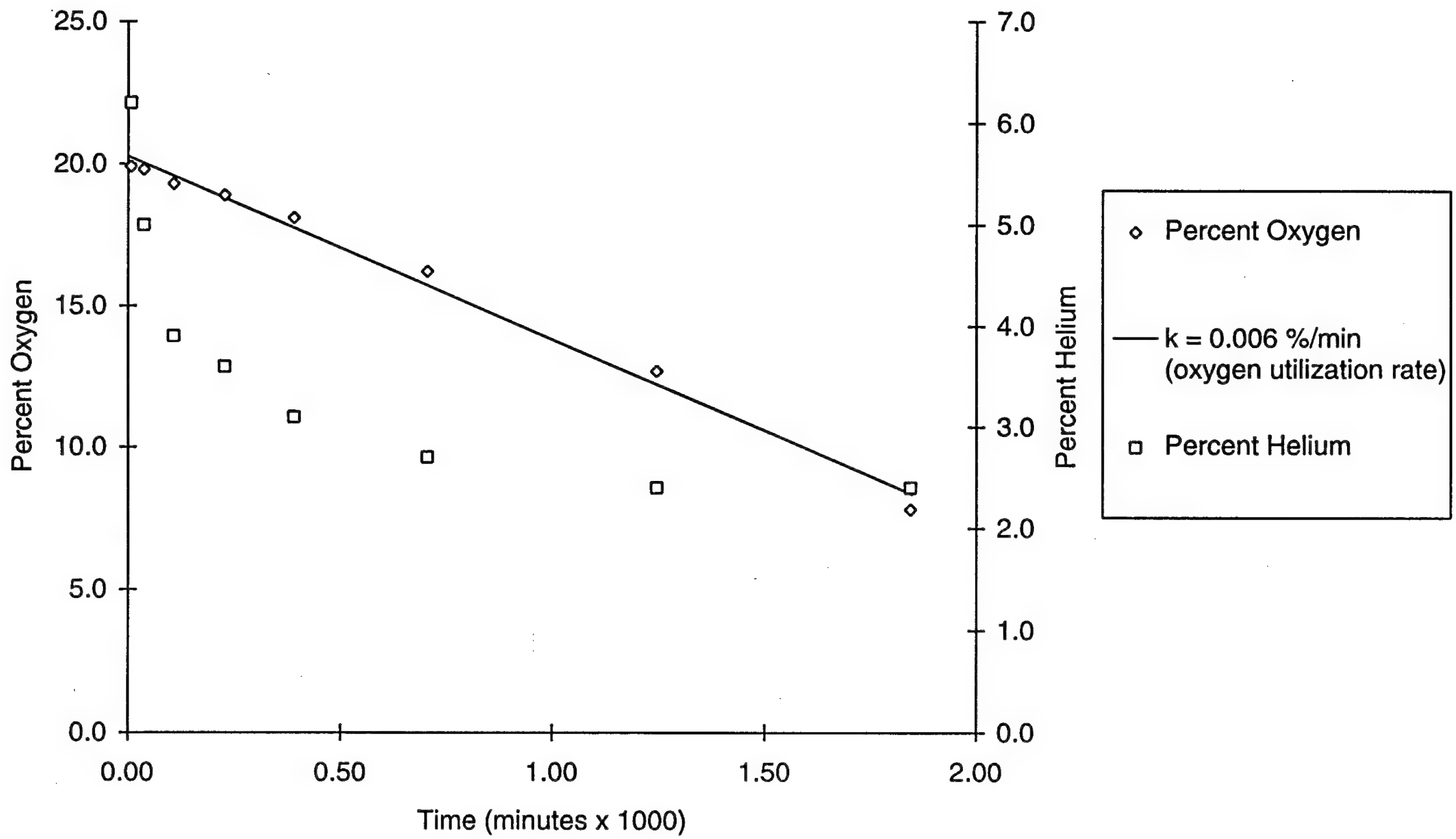
OXYGEN UTILIZATION DATA PLOTS
SITE SS-15

Initial Respiration Test
Site SS-15 (POL Depot)
Shaw AFB, SC

Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2	Total Hydro-carbon	Helium	Comments	New x-values	Trend of O2/ Time	k
SH1-MPA-12	10/06/94	0.00	11:52	0.00	0.00	0.01	19.9	0.3	84	6.2	Soil Temp = 72.1 deg. F	0	20.268286	0.006453
SH1-MPA-12	10/06/94	0.00	12:22	0.03	0.03	0.04	19.8	0.4	200	5.0		1.85	8.3297288	
SH1-MPA-12	10/06/94	0.00	13:32	0.07	0.07	0.11	19.3	0.3	680	3.9	Temp = 71.9 deg. F			
SH1-MPA-12	10/06/94	0.00	15:32	0.16	0.16	0.23	18.9	0.4	1,000	3.6	Temp = 72.5 deg. F			
SH1-MPA-12	10/06/94	0.00	18:15	0.27	0.27	0.39	18.1	0.4	1,000	3.1	Temp = 72.8 deg. F			
SH1-MPA-12	10/06/94	0.00	23:30	0.49	0.49	0.71	16.2	0.5	1,400	2.7	Temp = 73.5 deg. F			
SH1-MPA-12	10/07/94	1.00	08:30	-0.14	0.86	1.25	12.7	0.6	2,000	2.4				
SH1-MPA-12	10/07/94	1.00	18:30	0.28	1.28	1.85	7.8	0.6	2,000	2.4	Temp = 73.2 deg. F			
SH1-MPA-24	10/06/94	0.00	11:53	0.01	0.01	0.01	20.0	0.3	76	6.0	Soil Temp = 67.9 deg. F	0	20.213041	0.001641
SH1-MPA-24	10/06/94	0.00	12:23	0.03	0.03	0.04	19.9	0.3	210	5.3		1.85	17.177841	
SH1-MPA-24	10/06/94	0.00	13:33	0.08	0.08	0.11	19.8	0.2	720	3.7	Temp = 67.1 deg. F			
SH1-MPA-24	10/06/94	0.00	15:35	0.16	0.16	0.23	19.9	0.5	1,000	2.9	Temp = 67.4 deg. F			
SH1-MPA-24	10/06/94	0.00	18:15	0.27	0.27	0.39	19.9	0.3	1,000	2.4	Temp = 67.5 deg. F			
SH1-MPA-24	10/06/94	0.00	23:35	0.49	0.49	0.71	19.5	0.5	1,600	2.3				
SH1-MPA-24	10/07/94	1.00	08:30	-0.14	0.86	1.25	18.4	0.6	1,900	2.1	Temp = 68.1 deg. F			
SH1-MPA-24	10/07/94	1.00	18:30	0.28	1.28	1.85	16.8	0.6	1800	2.3	Temp = 68 deg. F			
SH1-MPA-38	10/06/94	0.00	11:55	0.01	0.01	0.01	20.0	0.25	180	6.0	Soil Temp = 63.5 deg. F	0	20.275983	0.003831
SH1-MPA-38	10/06/94	0.00	12:25	0.03	0.03	0.04	19.9	0.25	650	5.2		1.85	13.188397	
SH1-MPA-38	10/06/94	0.00	13:35	0.08	0.08	0.11	19.7	0.1	1,200	4.2	Temp = 64.8 deg. F			
SH1-MPA-38	10/06/94	0.00	15:38	0.16	0.16	0.23	19.5	0.3	1,800	3.9	Temp = 65.6 deg. F			
SH1-MPA-38	10/06/94	0.00	18:20	0.27	0.27	0.40	19.0	0.25	2,400	3.6	Temp = 66.0 deg. F			
SH1-MPA-38	10/06/94	0.00	23:40	0.50	0.50	0.72	17.9	0.40	3,500	3.1				
SH1-MPA-38	10/07/94	1.00	08:30	-0.14	0.86	1.25	15.8	0.40	5,300	2.6	Temp = 67.1 deg. F			
SH1-MPA-38	10/07/94	1.00	18:35	0.28	1.28	1.85	12.8	0.7	5200	2.5	Temp = 66.7 deg. F			
SH1-MPB-10	10/06/94	0.00	11:56	0.01	0.01	0.01	20.5	0.25	30	2.1	Soil Temp = 71.8 deg. F	0	20.603446	0.003634
SH1-MPB-10	10/06/94	0.00	12:26	0.03	0.03	0.04	20.3	0.4	40	2.0		1.86	13.844802	
SH1-MPB-10	10/06/94	0.00	13:42	0.08	0.08	0.12	19.9	0.4	100	1.8	Temp = 72.0 deg. F			
SH1-MPB-10	10/06/94	0.00	15:42	0.16	0.16	0.24	19.8	0.45	240	1.6	Temp = 72.3 deg. F			
SH1-MPB-10	10/06/94	0.00	18:20	0.27	0.27	0.40	19.8	0.5	320	1.6	Temp = 72.3 deg. F			
SH1-MPB-10	10/06/94	0.00	23:35	0.49	0.49	0.71	17.6	0.8	400	1.6				
SH1-MPB-10	10/07/94	1.00	08:50	-0.12	0.88	1.27	16.6	1.0	600	1.4	Temp = 73.3 deg. F			
SH1-MPB-10	10/07/94	1.00	18:40	0.29	1.29	1.86	13.5	0.6	700	1.0	Temp = 72.8 deg. F			
SH1-MPB-24	10/06/94	0.00	11:58	0.01	0.01	0.01	20.5	0.25	20	2.1		0	20.590676	0.002284
SH1-MPB-24	10/06/94	0.00	12:28	0.03	0.03	0.04	20.3	0.3	34	2.1		1.86	16.343254	
SH1-MPB-24	10/06/94	0.00	13:44	0.08	0.08	0.12	20.0	0.3	120	1.7				
SH1-MPB-24	10/06/94	0.00	15:48	0.17	0.17	0.24	20.1	0.45	220	1.2				
SH1-MPB-24	10/06/94	0.00	18:25	0.28	0.28	0.40	20.0	0.5	270	1.0				
SH1-MPB-24	10/06/94	0.00	23:35	0.49	0.49	0.71	19.2	0.7	380	1.0				
SH1-MPB-24	10/07/94	1.00	08:50	-0.12	0.88	1.27	18.0	0.7	620	1.1				
SH1-MPB-24	10/07/94	1.00	18:45	0.29	1.29	1.86	16.0	0.6	670	1.1				

SH1-MPB-38	10/06/94	0.00	11:59	0.01	0.01	0.01	20.0	0.25	160	5.3	Soil Temp = 66.5 deg. F	0	20.062836	0.000900
SH1-MPB-38	10/06/94	0.00	12:29	0.03	0.03	0.04	19.9	0.3	680	4.8		1.86	18.389677	
SH1-MPB-38	10/06/94	0.00	13:46	0.08	0.08	0.12	19.8	0.25	1,100	4.0	Temp = 66.2 deg. F			
SH1-MPB-38	10/06/94	0.00	15:53	0.17	0.17	0.25	20.0	0.25	1,300	2.9	Temp = 66.2 deg. F			
SH1-MPB-38	10/06/94	0.00	18:25	0.28	0.28	0.40	20.0	0.4	1,400	2.6	Temp = 66.2 deg. F			
SH1-MPB-38	10/06/94	0.00	23:40	0.50	0.50	0.72	19.8	0.6	3,800	2.4				
SH1-MPB-38	10/07/94	1.00	08:55	-0.12	0.88	1.27	18.0	0.5	3,500	2.1	Temp = 66.9 deg. F			
SH1-MPB-38	10/07/94	1.00	18:45	0.29	1.29	1.86	18.8	0.6	2,800	2.0	Temp = 66.5 deg. F			
SH1-MPC-20	10/06/94	0.00	12:00	0.01	0.01	0.02	20.5	0.2	20	2.1		0	20.527829	0.002186
SH1-MPC-20	10/06/94	0.00	12:30	0.03	0.03	0.05	20.5	0.4	48	2.0		1.87	16.439422	
SH1-MPC-20	10/06/94	0.00	13:30	0.07	0.07	0.11	20.0	0.4	56	1.4				
SH1-MPC-20	10/06/94	0.00	15:55	0.17	0.17	0.25	20.0	0.3	100	1.1	Switch meters			
SH1-MPC-20	10/06/94	0.00	18:15	0.27	0.27	0.39	19.9	0.5	76	1.2				
SH1-MPC-20	10/06/94	0.00	23:30	0.49	0.49	0.71	19.0	0.6	100	1.0				
SH1-MPC-20	10/07/94	1.00	08:40	-0.13	0.87	1.26	17.8	0.6	210	1.0				
SH1-MPC-20	10/07/94	1.00	18:50	0.30	1.30	1.87	16.4	0.5	100	0.99				
SH1-MPC-38	10/06/94	0.00	12:00	0.01	0.01	0.02	20.2	0.2	360	2.1		0	20.251097	0.001830
SH1-MPC-38	10/06/94	0.00	12:30	0.03	0.03	0.05	20.2	0.4	1,000	2.0		1.87	16.829288	
SH1-MPC-38	10/06/94	0.00	13:30	0.07	0.07	0.11	20.0	0.4	1,850	1.6				
SH1-MPC-38	10/06/94	0.00	16:00	0.18	0.18	0.26	20.0	0.4	1,600	1.4	Switch meters			
SH1-MPC-38	10/06/94	0.00	18:20	0.27	0.27	0.40	19.5	0.6	2,000	1.3				
SH1-MPC-38	10/06/94	0.00	23:30	0.49	0.49	0.71	18.8	0.7	4,000	1.1				
SH1-MPC-38	10/07/94	1.00	08:45	-0.13	0.88	1.26	17.9	0.75	4,800	1.0				
SH1-MPC-38	10/07/94	1.00	18:55	0.30	1.30	1.87	16.9	0.8	5,500	0.99				
MW-607	10/06/94	0.00	12:00	0.01	0.01	0.02	20.0	0.2	340	5.3		0	20.096256	0.001300
MW-607	10/06/94	0.00	12:30	0.03	0.03	0.05	19.8	0.2	640	5.4		1.88	17.652117	
MW-607	10/06/94	0.00	13:30	0.07	0.07	0.11	19.9	0.45	1,800	2.9				
MW-607	10/06/94	0.00	16:04	0.18	0.18	0.26	20.0	0.4	1,650	3.1	Switch meters			
MW-607	10/06/94	0.00	18:25	0.28	0.28	0.40	19.9	0.6	4,000	2.3				
MW-607	10/06/94	0.00	23:35	0.49	0.49	0.71	19.1	0.7	5,500	2.1				
MW-607	10/07/94	1.00	08:45	-0.13	0.88	1.26	18.3	0.8	7,300	2.0				
MW-607	10/07/94	1.00	19:00	0.30	1.30	1.88	17.7	0.8	>10,000	1.90				

Respiration Test
Site SS-15 - SH1-MPA-12
Shaw AFB, SC



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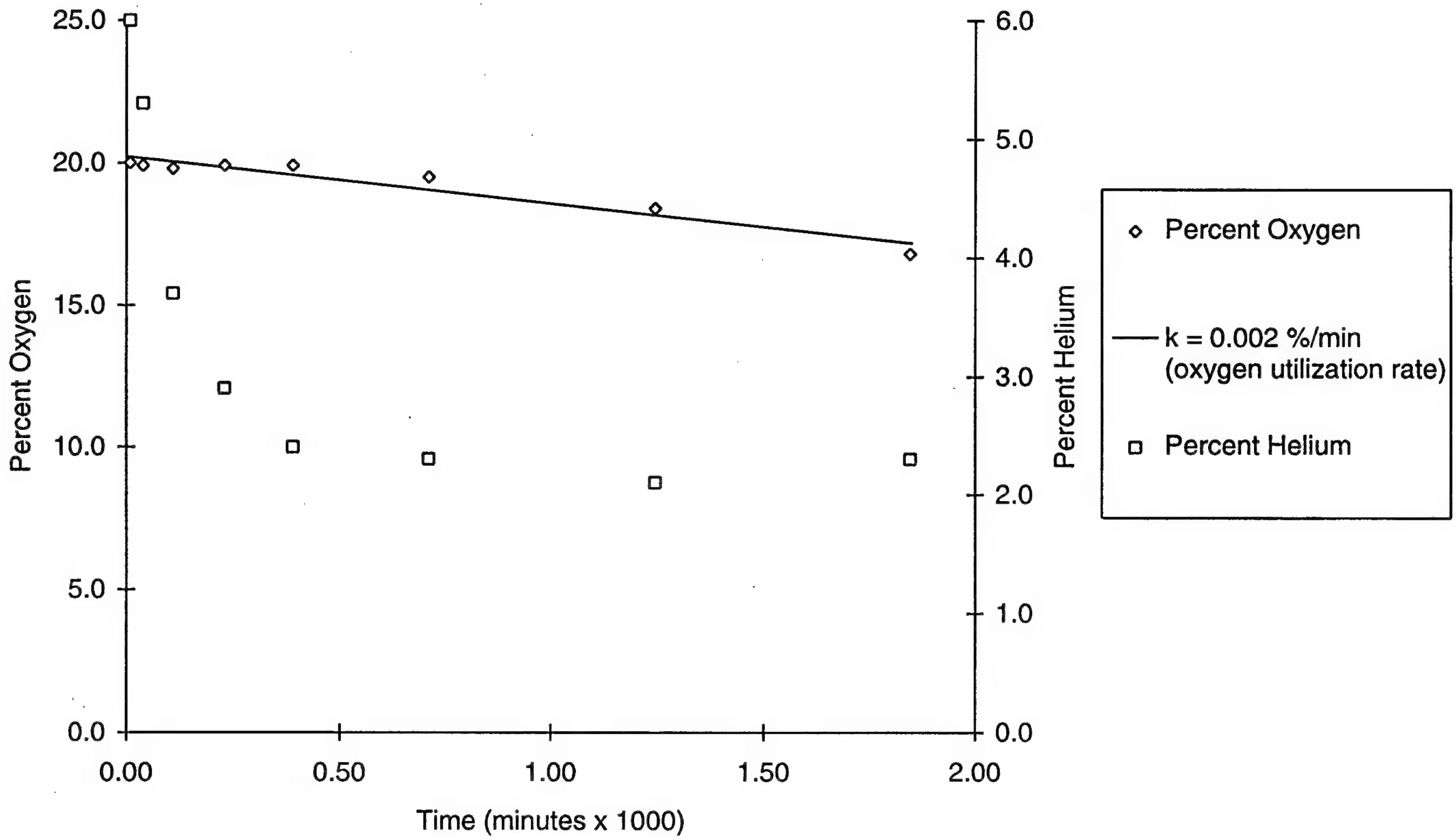
Respiration Test
Site SS-15 - SH1-MPA-24
Shaw AFB, SC



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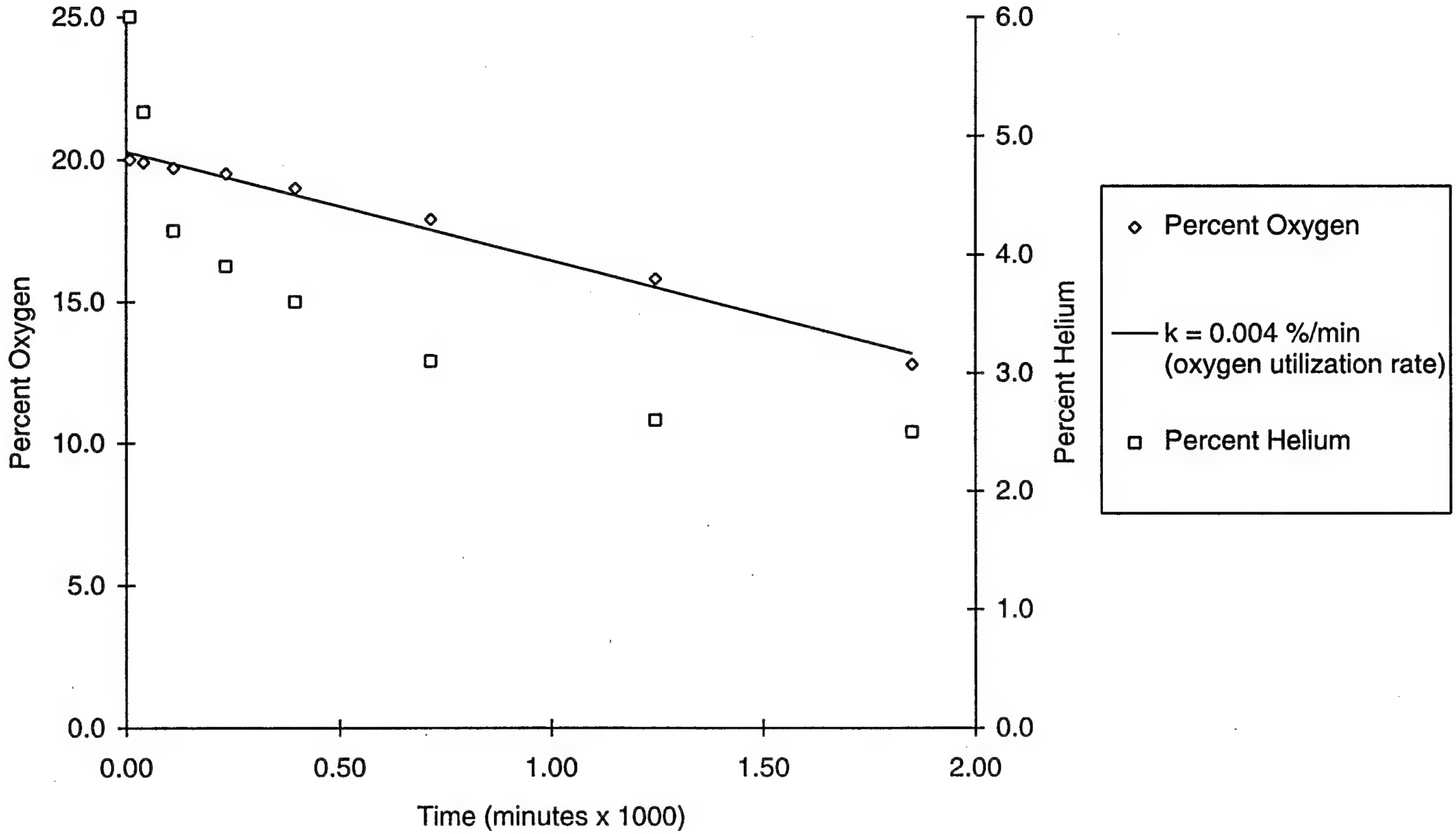
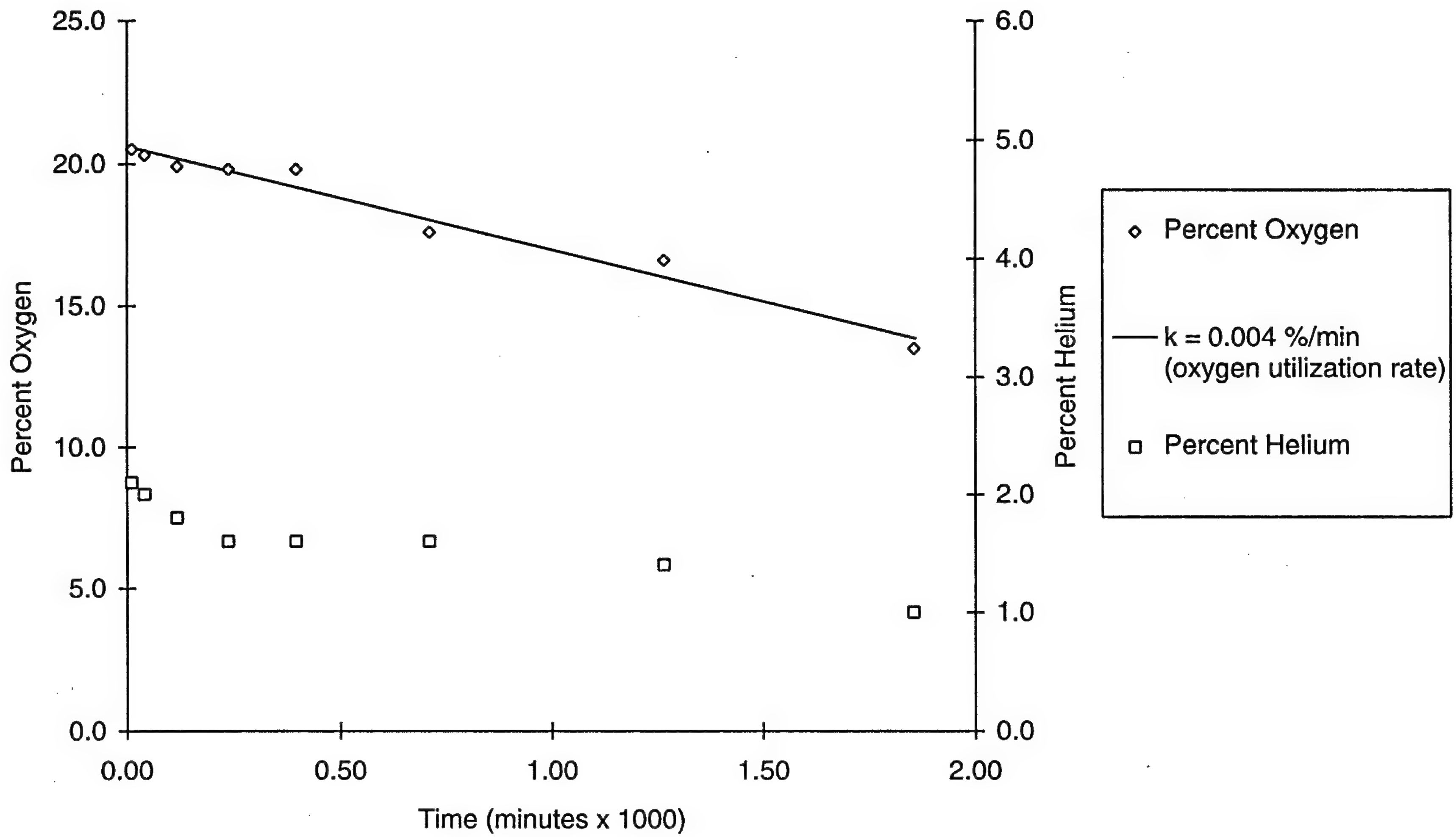
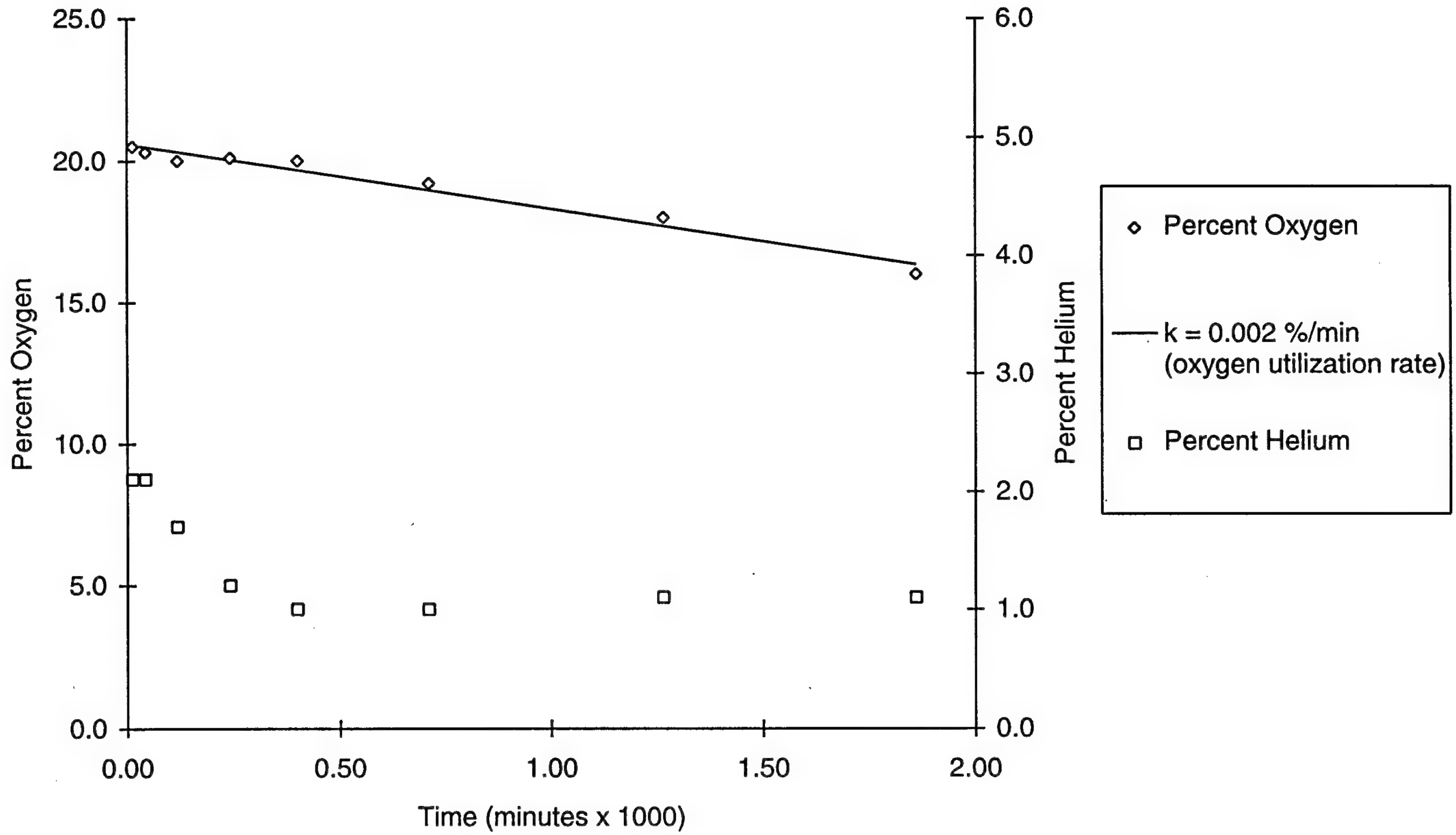
Respiration Test
Site SS-15 - SH1-MPA-38
Shaw AFB, SC



Respiration Test
Site SS-15 - SH1-MPB-10
Shaw AFB, SC



Respiration Test
Site SS-15 - SH1-MPB-24
Shaw AFB, SC



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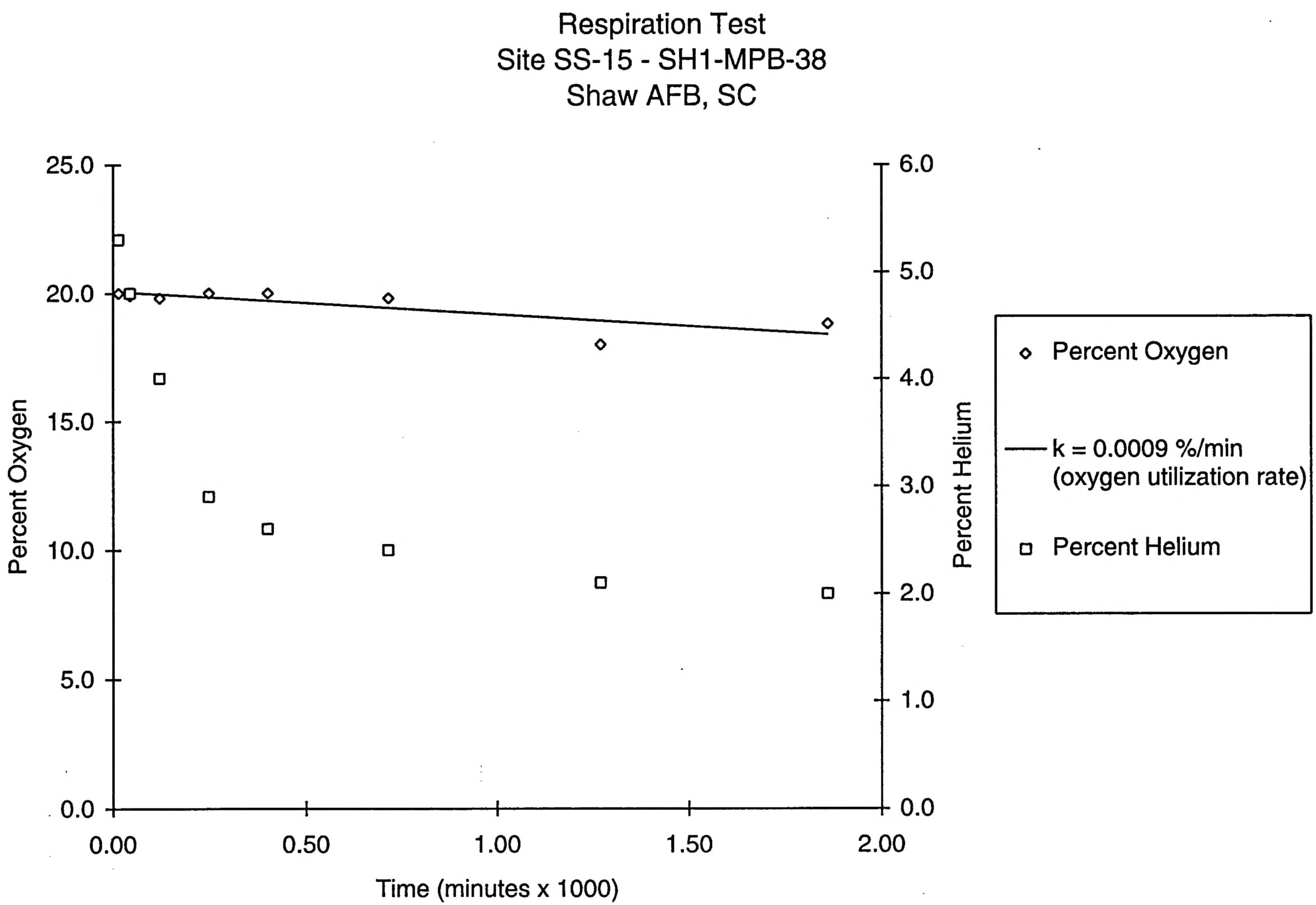
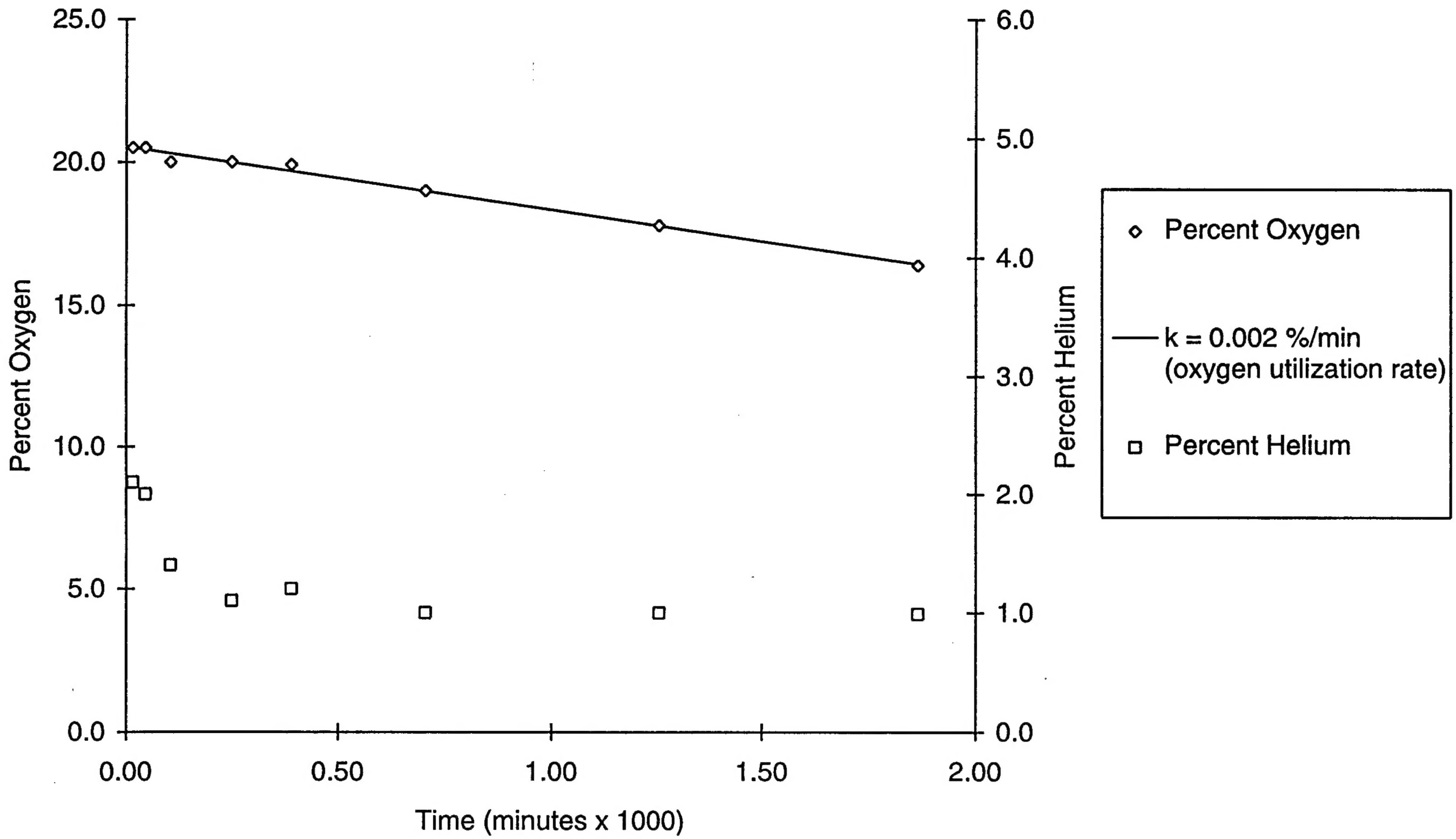
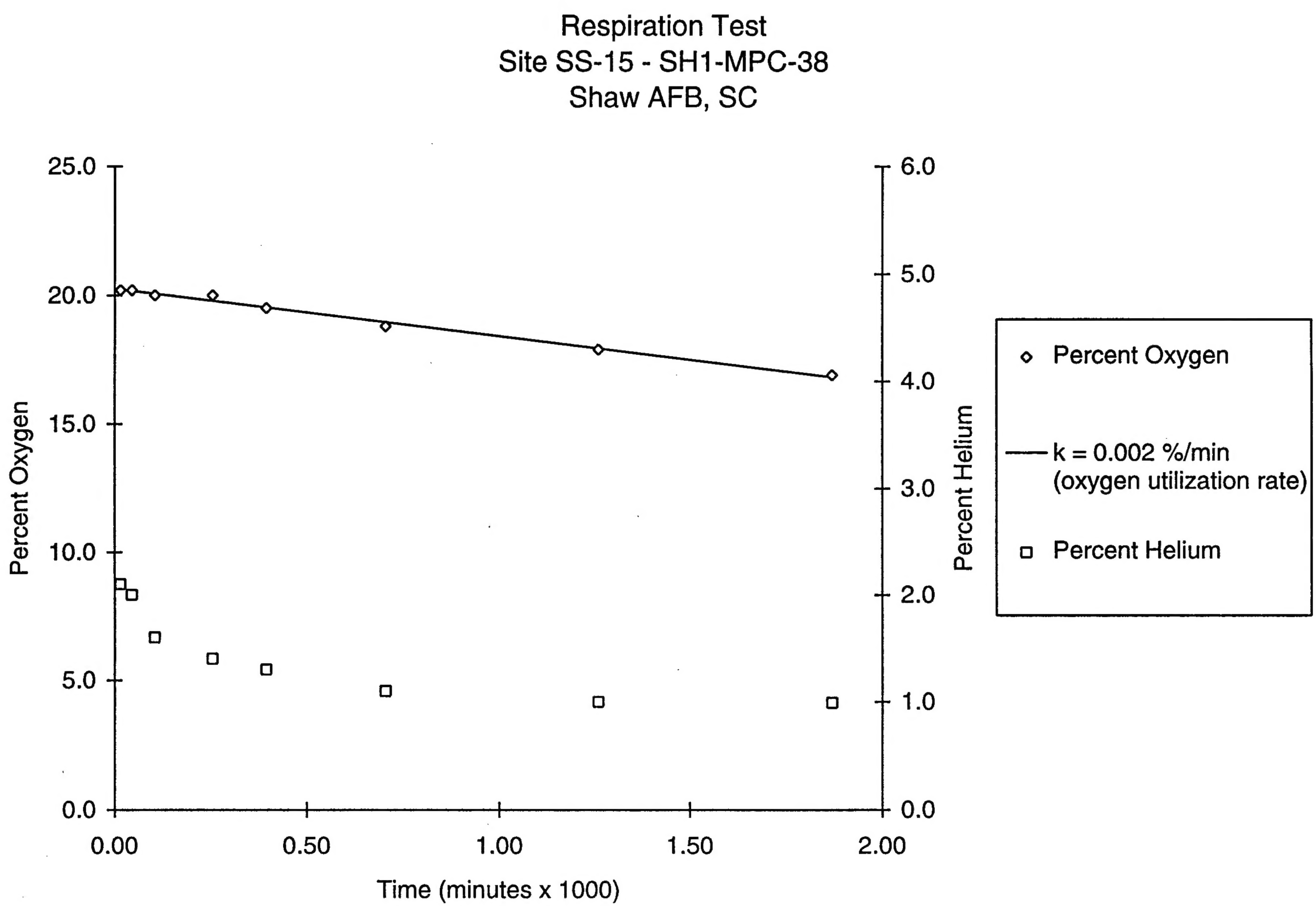

Respiration Test
Site SS-15 - SH1-MPB-38
Shaw AFB, SC
25.0
20.0
15.0
10.0
5.0
0.0
Percent Oxygen
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Percent Helium
0.00
0.50
1.00
1.50
2.00
Time (minutes x 1000)
Percent Oxygen
k = 0.0009 %/min
(oxygen utilization rate)
Percent Helium

Respiration Test
Site SS-15 - SH1-MPC-20
Shaw AFB, SC





SHAWSS15.XLS

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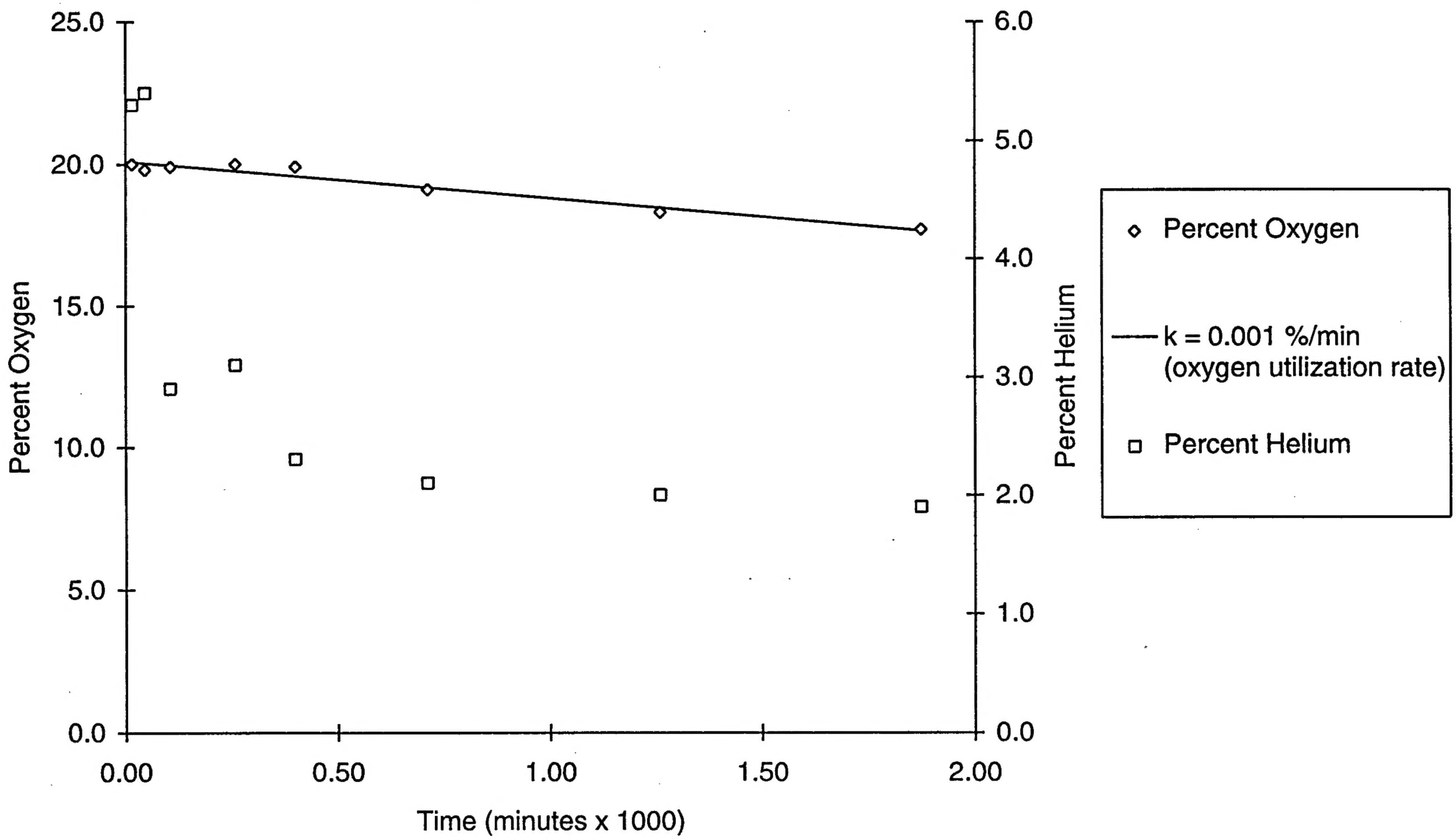
Respiration Test
Site SS-15 - MW-607
Shaw AFB, SC



SHAWSS15.XLS

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